Eng. dit

GENERAL LIBRARY
UNIV. OF MICH.
NOV 17 1911

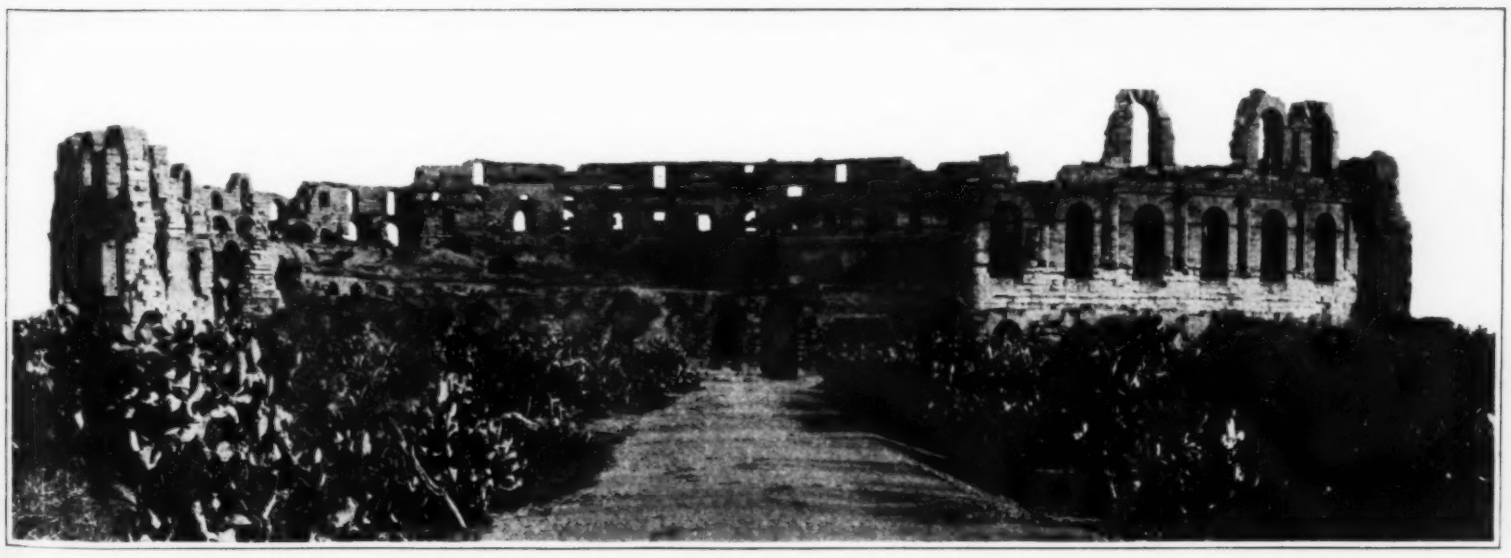
SCIENTIFIC AMERICAN
SUPPLEMENT, No. 1872

Entered at the Post Office of New York, N. Y., as Second Class Matter.
Copyright, 1911, by Munn & Co., Inc.
Published weekly by Munn & Co., Inc., at 361 Broadway, New York.
Charles Allen Munn, President, 361 Broadway, New York.
Frederick Converse Beach, Sec'y and Treas., 361 Broadway, New York.

Scientific American, established 1845.
Scientific American Supplement, Vol. LXXII., No. 1872. NEW YORK, NOVEMBER 18, 1911. Scientific American Supplement, $5 a year.
Scientific American and Supplement, $7 a year.

Roman Ruins in North Africa

The Medracen, Which is Probably a Mausoleum for the Ancient Kings of Numidia.



Amphitheater of El Djem—One of the Largest and Best Preserved Amphitheaters Extant.

RELICS OF AN ANCIENT COLONY—[See page 324.]

Alloys

An Unlimited Field for Research and Invention

By Albert A. Somerville

THE pure metals are used for comparatively few purposes. For the manufacture of nearly every metallic article in use to-day an alloy is found to be better than any of its constituents taken alone.

Alloys as most commonly considered are mixtures of metals, though iron unites with carbon, a non-metal, and the product is known as the alloy, steel. When mercury is one of the combining metals the result thereof is termed an amalgam instead of an alloy.

Considering all the permutations and combinations possible the number of alloys possible is almost infinite, and each one is different from all the others. To begin, consider, (1) one metal combined with every other metal taken one at a time and the metals mixed being in equal proportions. This makes a considerable number of mixtures, as many as there are metals, less one. If x is the total number of metals then $x-1$ is the number of mixtures. x the number of metals will be at least 70, so we have 69 mixtures.

(2) Then combine *each* metal with every other metal taken one at a time, the metals mixed being in equal proportions. Now the number of mixtures will be $(x-1)\frac{x}{2}$ or $(70-1)\frac{70}{2}$ or 2,415.

(3) Instead of mixing the two metals in equal proportions vary the percentages from 1 to 99 for each element in each mixture formed. The number of combinations now at hand will be given by the product of $(x-1)\frac{x}{(2)} \times 99$ or 239,085.

(4) Now instead of making only two-metal mixtures, add a third metal to each of the products we have already formed. There are 68 metals we can add to each of the 239,085 formed in (3) or a total now of 16,257,780 alloys formed.

(5) Now these last added metals may be in varying proportions and then also other metals may be added subsequently until figures are reached that have no meaning.

Of course you will say that not nearly all of these combinations can be effected. Maybe not, but if only just a small part of them can be made, that small portion represents an enormous number with still greater possibilities beyond.

There are two general theories concerning the formation of alloys.

1. Solution.

If one metal is in a molten state, another metal in a solid state may dissolve if placed in the liquid mass, somewhat in the same way as salt goes into solution when placed in water. However, the water will dissolve only a certain amount of salt, until it becomes a saturated solution, so salt and water can be alloyed or dissolved only in certain limiting proportions. The same may be said of two metals, so it is not always possible to get an alloy bearing any or every percentage of some metal with another.

Again, water will not dissolve everything as it does salt. Likewise not all metals will go into solution with all other metals. Also as a saturated solution of brine cools, some of the salt will crystallize out of the solution, similarly some metals that become thoroughly mixed at one temperature may separate out again as the solution or mixture cools and especially is this so just as the mixture solidifies.

2. Chemical.

Some claim that when metals are united to form alloys their atomic proportions should be maintained in multiples of their respective proportional numbers, otherwise the mixture will lack uniformity and will appear mottled where fractured, and its constituent parts will have different expansibility and elasticity constants and have a tendency to disintegrate under the action of heat or motion.

The idea is that if the atomic proportions do not bear a constant multiple throughout, then there are two entirely different combinations formed which have different physical constants and hence a fracture will naturally occur at a place where there is a lack of uniformity and a mottled appearance will be due to this variation throughout the mixture.

Surface alloys are sometimes made by electroplating a thin layer of fine metal on to a baser metal and the two intermix where the surfaces are in contact. Another method is to immerse one metal in a bath consisting of the dust of another metal and subject the whole to an increased temperature but below that of the melting point of the metallic dust. The solid metal becomes thoroughly coated and impregnated for a slight depth with the metal of which the dust consists.

Mixture by fusion is the general commercial method of making an alloy. Then there are two general ways of mixing by fusion.

One of these is to melt each of the several different metals entering into the alloy, one at a time, beginning with that one which has the highest melting point; when this is melted the metal having the next highest melting point is added to the already molten mass. This plan is continued until all the different constituents are melted, the one having the lowest melting point going into the mixture last. This is to prevent as much as possible volatilization of those metals which would more easily pass into the vapor state.

The other method of mixing by fusion is to place all the entering metals, in a finely chopped or ground condition, in the crucible and to heat the whole mass at the same time. In this case the top of the crucible is filled with finely ground or powdered charcoal or carbon in order to prevent oxidation of the metals.

Before pouring, the mass is thoroughly stirred with a carbon rod, carbon being used in order to take up the oxygen that may be given off by the hot metal. The stirring is done in order to make a homogeneous mixture, the denser metals tending to settle at the bottom. Sometimes if there are impurities present, and impurities are only other metals present in small quantities, they are got rid of by means of oxidation, and it requires a training acquired only by practice to know just when to pour into the mold.

The molds are frequently in the form of long, narrow troughs containing inverted V's at regular distances along the bottom. This mold then makes a casting with V-shaped notches along it at regular intervals allowing it to be readily broken up into convenient sized ingots.

The heating is accomplished by means of coal, coke or charcoal, gas, electricity or crude oil. Electrical furnaces are being used almost exclusively in laboratories but as yet electrical energy is too expensive for use for heating purposes on a commercial scale. Crude oil is now being employed to furnish heat in the manufacturing plants, being cheaper than gas and more easily controlled than is a coal fire. The oil is sprayed into the furnace, thereby better effecting combustion so that great clouds of smoke do not issue from chimneys as where coal is used.

Clay crucibles are used and where fine alloys are being made the crucibles are discarded after they become covered with oxide. The new and unused crucibles are kept on top or near the furnaces in order that they may be thoroughly dry when wanted for use. Nothing is more dangerous in a foundry than the "exploding of molten metal," as it is called, due to vapor of water forming under pressure, and as another precaution a cold metal is never dropped into a molten mass, but is first heated enough to drive off any moisture present.

The alchemists have never succeeded in turning the baser metals into gold, which fond ideal was their dream, but the metallurgists are every day making alloys which are more valuable than any of the metals that enter into the alloy.

These alloys are being made into castings, wires, tubes, rods, plates and sheets.

Their physical properties, melting point, density, hardness, ductility, malleability, toughness, electrical resistance, temperature coefficient of electrical resistance, thermal conductivity, thermal electro-motive force, tensile strength may be greater or less than those of any of the components entering into the alloy. Nearly all these properties are affected by the way in which the alloy is tempered or annealed. After being cast it is "pickled" in baths containing the proper chemicals to remove the surface oxide formed and then baked in a furnace of varying temperatures in different parts so that any temperature desired can be had at hand at once. Then at a definite time and temperature the ingot may be drawn out and sprayed with cold water or it may be left in the furnace to cool slowly. In either case it is necessary to "pickle" it again in order to remove the oxide just formed and in case a highly polished surface is desired it is scratched all over or literally "shaved" in order to remove every trace of anything foreign.

If two metals enter into the alloy, the melting point of the mixture will probably be less than that of either metal alone. If several mixtures are made up, varying the proportions of the two metals used, the melting point of each mixture may be determined and a curve drawn showing the temperature for an alloy made of the two metals in question used in any proportion. At some definite place there will be a minimum point on this curve indicating the lowest melting point that can be attained by any mixture of those two metals and that particular proportion is known as the "Eutectic" mixture of those two metals.

Naturally these curves become more complicated where more than two metals make up the alloy. This ability to vary almost at will the melting point of a composition is a valuable acquisition and is made use of in the manufacture of automatic fire alarms, safety devices and electric fuses. Modern buildings are now generally equipped with these safety devices, they being adjusted to operate at a temperature slightly above that which would ever be reached in the building under normal summer atmospheric conditions and of course all electric lines are equipped with some kind of a safety fuse or switch to prevent abnormally large currents which would produce much heat and cause danger of fire.

For electrical purposes metals may be mixed to produce a higher specific resistance than is possessed by any pure metal. Also the alloy may be made that will not readily oxidize at high temperatures and so may be used to carry current and act as an electrical heater or furnace. Again they may be made to have a very small temperature coefficient of electrical resistance and so are used universally in the manufacture of resistance boxes.

The general rule is that an alloy possesses a higher specific resistance and a smaller temperature coefficient of resistance than any of the pure metals used to make the alloy. However, knowing the constants of the pure metals one cannot at present forecast in any wise what the properties of the alloy will be which they form.

The thermal-electro-motive force of alloys is another big field for investigation and offers alluring attractions since it is one of the methods proposed, and, by the way, not an impossible one, for obtaining energy from the sun; and reports are that in some places where there is much sunshine some of these plants have been installed. The commercial value of a successful venture of this kind would be greater than any Utopian dream. The practical purpose to which thermo-junctions are now put is the measurement of high temperatures.

Frequently the addition of just a small per cent of one metal to another makes marked changes in the properties of the metal used in the greater proportion. It may disturb some people greatly to learn that their good money is not all pure metal, that a nickel is one-fourth copper, a dollar contains some copper, their gold coins are not pure and even a copper cent is not all copper. Coinage is subject to a great deal of wear as is evidenced by the smoothness of the coins that come into one's possession, so they are alloyed to make them harder and so better withstand wear. This property of hardness also depends upon tempering. Much has been said and written upon the so-called lost art of tempering or heat treatment of copper to harden it.

Heretofore iron, nickel and cobalt were known as the only magnetic substances but now alloys are being made which are magnetic and yet contain none of those three named elements. The hysteresis effect in iron has been so reduced as to make it much more valuable for use in electro-dynamo machinery.

Alloys have been made that are nearly non-arcing, or at least so advertised, and by the way of contrast, alloys are now made that will make a spark readily when the proper material is drawn across them and so in a way promise to supersede the parlor match at least for some purposes.

Bearings are now made of composition metal which insures great smoothness and consequently a minimum amount of heating by friction. Springs are made of materials, none of the elements of which are "springy" or elastic. Alloys are made that work much easier in the lathe than the pure metals and when finished make a better product.

For purposes utilitarian, metals used pure are almost out of the race and for both ornamental purposes and commercial reasons the alloy is receiving much attention. Processes are patented and the rights jealously guarded. The products are advertised under trade names which may or may not indicate either their possible use or probable composition. And the metallurgists are discovering new processes and new products almost daily.

A Proposed Catalytic Furnace

Especially Designed for Heating Steel Billets

By E. C. Smith

THE catalytic property of certain metals and other mineral substances to influence the chemical combustion of hydrogen and oxygen gases was first discovered by Sir Humphry Davy, and subsequently investigated by Edmund Davy, Doebereiner, De la Rive, Faraday, and Liebig; however, it advanced but little beyond the laboratory stage until the last few years. The first application of catalytic action to the industrial arts was made by Peregrine Phillips, a manufacturer of Bristol, England, who applied it to the manufacture of vinegar. A further application of it was made by the Belgian chemist, Schneider, who alleged at the time that he had solved the problem of manufacturing sulphuric acid without the aid of leaden chambers. Later, Winkler and Dr. Knietsch used this principle in the manufacture of sulphuric acid and so far lessened the costs by such use that the cost to-day does not exceed one cent per pound. Indigo,to-day, is produced by catalytic action of mercury, and the amount so manufactured would require the cultivation on an area of more than one-quarter of a million acres of land in the home of the indigo plant.

Four years ago the writer patented the application of this catalytic action to the heating of furnaces. He discovered that where oxygen and hydrogen gases were confined in cells, separated from each other by dividing walls made of porous material and composed partly of a catalytic agent, and a slight pressure was given to one of the gases, that gas was caused to pass through the porous dividing plate in an extremely finely divided state. In this divided state the gas so forced through the wall meets the other gas in the presence of the catalytic agent and a rapid oxidation takes place. The chemical affinity of the two is so great as to cause a rise in temperature in the catalytic agent and, therefore, in the material of the porous plate. The chemical combination of the two gases is increased or decreased at the will of the operator controlling the furnace by simply increasing or decreasing the pressure of the gas passing through the porous plate.

It must be understood that the catalytic agent plays only the part of a *combining* agent in getting the two gases together into chemical combination, and itself becomes no part of the product of the combination. The catalytic agent, therefore, remains in the same chemical form, no matter how long it may be in use, whether one hour or one year.

It will be readily seen that this mode of combustion—for "combustion" is simply another and older term given to the same chemical action—insures a positive combination of the gases in their chemical proportion and insures also that every molecule of gas passing through the plate is acted upon by the catalytic agent. Any undeveloped or unused gas or fuel, therefore, cannot escape the action of the catalytic agent, and hence all the heat units of the fuel are developed.

The useful application of the heat supplied becomes then merely a matter of furnace design, which, in turn, depends on the character of the objects to be heated, the application in view at present being the automatic reheating of billets, bar steel, etc.

The furnace in general interior and exterior appearance, its operation and its automatic handling of the objects to be heated, is wholly unlike any other furnace.

The exterior side elevation presents a view not unlike an immense cannon some fifty feet or more in length, its outward end inclined to an elevation of twenty-five degrees. Both ends of the tubular furnace are open. A heavy endless chain having links carrying refractory clay saddles, on which steel billets may rest, travels the entire length of the furnace and deposits its heated freight at the lower opening.

In cross-section an inner chamber or furnace bed proper is presented to view extending from end to end of the furnace, along the bottom of which ride on suitable ways the linked saddles. The walls of this tubular chamber present an unbroken surface of refractory plates extending from end to end of the furnace. Incircling this tubular furnace chamber, from end to end, are located a large number of vertically arranged, hollow, horn-shaped segments made of a porous and highly refractory material, each segment having its lower end connected with a gas pipe through which oxygen gas under any desired degree of pressure may be forced. These horns are so shaped that their faces present an unbroken series of accordion pleats, the angles of which converge toward the furnace chamber proper. Their outer surfaces are coated with finely divided, reduced platinum. These hollow, horn-like, porous structures are the heat generators proper. There are some 300 horns along each side, or 600 in all for the entire fifty feet of furnace, the combined area of the catalytic or heat-generating surface amounting to some 3,000 square feet. The spaces formed by the converging sides of these catalytic plates and the outer wall of the furnace chamber make separate chambers or passageways for hydrogen gas, such chamber being separately connected with a system of pipes leading from a hydrogen tank. The entire heating energies of these plates are concentrated on the path along which the steel blooms are being conveyed through the tubular furnace bed.

The gases oxygen and hydrogen, when combined in bulk, form a most violent explosive and are for that reason kept in separate tanks and provided with separate paths of entrance to the furnaces. Within the furnace they are kept separate by isolating the oxygen within the porous horn-like plates and the oxygen is minutely divided as it finds its way through the plates and only approaches the hydrogen in a molecular state by passing the platinum coating of these plates. Hence the combination of the two gases is placed under the direct control of the pressure valves.

The operation of raising a working temperature within the furnace is one of exceeding simplicity and is performed by turning on the valves controlling the two gases. The oxygen enters the porous horns and passes through the pores and coming into intimate and simultaneous contact with both the platinum and the hydrogen, the aforesaid physical property of the platinum is excited, the oxygen and the hydrogen energetically combine, heat is evolved, and other quantities of oxygen and hydrogen are successively and rapidly combined. The temperature of the platinum and the walls in which it is imbedded increasing rapidly, there is a corresponding acceleration in the rapidity of the combination of gases. This state of things continues so long as the pressure of gases is maintained, and decreases when the gases are turned off.

The unusual length given to the furnace, combined with the means providing for the perfect control and maintenance of the temperature at any desired heat, insures a perfect saturation of the billets to a forging heat, though they may be conveyed through the furnace with great rapidity.

Rules Governing the Competition for the $15,000 Flying Machine Prize Offered by Mr. Edwin Gould

1. A PRIZE of $15,000 has been offered by Mr. Edwin Gould for the most perfect and practicable heavier-than-air flying machine, designed and demonstrated in this country, and equipped with two or more compiete power plants (separate motors and propellers), so connected that any power plant may be operated independently, or that they may be used together.

CONDITIONS OF ENTRY.

2. Competitors for the prize must file with the Contest Committee complete drawings and specifications of their machines, in which the arrangement of the engines and propellers is clearly shown, with the mechanism for throwing into or out of gear one or all of the engines and propellers. Such entry should be addressed to the Contest Committee of the GOULD-SCIENTIFIC AMERICAN Prize, 361 Broadway, New York city. Each contestant, in formally entering his machine, must specify its type (monoplane, biplane, helicopter, etc.), give its principal dimensions, the number and sizes of its motors and propellers, its horse-power fuel-carrying capacity, and the nature of its steering and controlling devices.

3. Entries must be received at the office of the SCIENTIFIC AMERICAN on or before June 1st, 1912. Contests will take place July 4th, 1912, and following days. At least two machines must be entered in the contest or the prize will not be awarded.

CONTEST COMMITTEE.

4. The committee will consist of a representative of the SCIENTIFIC AMERICAN, a representative of the Aero Club of America, and the representative of some technical institute. This committee shall pass upon the practicability and efficiency of all the machines entered in competition, and they shall also act as judges in determining which machine has made the best flights and complied with the tests upon which the winning of the prize is conditional. The decision of this committee shall be final.

CONDITIONS OF THE TEST.

5. Before making a flight each contestant or his agent must prove to the satisfaction of the Contest Committee that he is able to drive each engine and propeller independently of the other or others, and that he is able to couple up all engines and propellers and drive them in unison. No machine will be allowed to compete unless it can fulfill these requirements to the satisfaction of the Contest Committee. The prize shall not be awarded unless the competitor can demonstrate that he is able to drive his machine in a continuous flight, over a designated course; and for a period of at least one hour he must run with one of his power plants disconnected; also he must drive his engines during said flight alternately and together. Recording tachometers attached to the motors can probably be used to prove such performance.

In the judging of the performances of the various machines, the questions of stability, ease of control and safety will also be taken into consideration by the judges. The machine best fulfilling these conditions shall be awarded the prize.

6. All heavier-than-air machines of any type whatever—aeroplanes, helicopters, ornithopters, etc.—shall be entitled to compete for the prize, but all machines carrying a balloon or gas-containing envelope for purposes of support are excluded from the competition.

7. The flights will be made under reasonable conditions of weather. The judges will, at their discretion, order the flights to begin at any time they may see fit, provided they consider the weather conditions sufficiently favorable.

8. No entry fee will be charged, but the contestant must pay for the transportation of his machine to and from the field of trial.

9. The place of holding the trial shall be determined by the Contest Committee, and the location of such place of trial shall be announced on or about June 1st, 1912.

10. Mr. Edwin Gould, Munn & Co., Inc., publishers of the SCIENTIFIC AMERICAN, and the judges who will be selected to pass upon machines, are not to be held responsible for any accident which may occur in storing or demonstrating the machines on the testing ground.

Use for Old Blueprints

IN the engineering department of every mine office, blueprints will accumulate until the quantity has reached amazing proportions. Some companies keep a record and file of all prints made and at periodical times destroy the old ones. In addition to this, at the time of printing, there is sure to be a certain waste due to poor exposures, blotchy paper, etc. A method for turning this waste into a useful article is presented by E. B. Birkenbend, *American Machinist*, of July 27th, 1911.

These old or useless prints may be bleached by immersing them in a soda bath containing four ounces of soda to one gallon of water. If it is desired to bleach only a portion of the print, this may be done by painting that part with this solution. By washing the prints in fresh water, after bleaching, any discoloration is prevented. The blank paper thus obtained furnishes a fair grade of sketch paper, and there are numerous other uses to which it could also be put.—*Engineering and Mining Journal.*

Identification of Charred Corpses by Means of X-Rays

THE catastrophe to the French warship "Liberté" furnishes an occasion to recall the communication of M. Foreau de Courneleis, to the French Institute in 1897, according to which, says *Cosmos*, many charred bodies can be identified by an X-ray examination of the bones, if the persons sought are known to have suffered from fractures, osteitis, or other morbid condition of the bones which caused a modification of the mineral composition in certain parts of the skeleton. In the present high development of radiography, which, as our readers know, can now be carried out by instantaneous methods, it should be possible to rapidly examine a large number of bones, and often to establish identifications which would be impossible by any other method.

Roman Ruins in North Africa

Historic Remains of an Ancient Colony

By Our Paris Correspondent

THE Roman remains which occur in northern Africa are not so well known as those of Europe. This is due largely to the fact that many of them, and among these some of the most remarkable, are now swallowed up by the desert and far from human habitations. The most striking of all such ruins are those of Timgad, the African Pompeii, as it is often called. Much of the ancient city has been uncovered, and new finds are being made almost every day.

The walls of Timgad (the ancient Thamugadi) still stand, with some of their principal gates, to the present day. We still see the main avenues, the forum, numerous temples and many other public buildings and dwelling houses. The plan on which the streets and houses are laid out differs somewhat from that of Pompeii, each house being detached, with passages surrounding it on

The Medracen—A Close View, Showing Some Details.

all sides. This arrangement was adopted in later times in Rome, after the great fire during the reign of Nero, and no doubt the newer cities followed the same plan.

One of the large buildings is the market, which was laid out around a central court with a fountain in the center. The market stalls are still in place, and before each is a stone counter fitted across the walls so that there was no way of entering except by climbing over this counter, an arrangement which may still be seen in the Arab bazaars of our day. In ancient times the market must have presented an animated scene. A variety of articles have been found at this site, which betoken its former function, such as weighing scales, vases, cups and wine bottles.

In addition to the many smaller dwellings in Timgad, there are found large houses, luxuriously fitted out, erstwhile the residences of wealthy citizens. One of these is the house of Sertius, which is well provided with hot and cold baths for the proprietors and also with separate accommodations for the domestics. In the rear is the women's apartment, and here we find an inner court, surrounded by a colonnade, so as to give shelter from the sun. Before it are two galleries, one of which is paved with bluish green mosaic, and the second with a mosaic of terra cotta tile. The main court or peristyle is laid with a flat stone paving in an excellent state of preservation. A pool, with a curbing of stones set up edgewise, is situated in the middle of the court, and in this part of the house there are several other pools. One of these was, no doubt, a fish pond. It has an upper and lower basin, separated by a false bottom with a stone stopper, so that the fish could take refuge in the lower part while the upper was being cleaned. Imbedded in the cement lining of the lower basin are twenty-two pottery vases, no doubt to give shelter to the fish when laying their eggs. An inscription found in the house shows that it belonged to Faustus Sertius and his wife, Valentina. Sertius was one of the principal citizens of Timgad and also donated the market building.

Timgad had no less than five bathing establishments, and all of these were laid out for hot and cold baths, about on the same plan as we find them at Pompeii. In the warm climate of Africa the use of baths was, of course, even more necessary than in the more northern regions. The largest of the baths is situated a short distance outside the walls, and it was, no doubt, one of the principal centers for recreation, about like our modern casino, and here the older well-to-do citizens or the young men passed the greater part of their time. It is a fine structure, having four entrances and containing thirty-five rooms. Three principal halls lie in the center of the building and were used for promenading or conversation, gymnastic exercises or games. The large central hall is the finest. It was surrounded by marble statues, and had a handsome mosaic floor. Around it are three swimming bath pools, and it is curious to see the writing or drawings which cover the cement lining, such as a ship in full sail, a hunting scene with the hare and hounds, gladiators, fights, and many other figures of men and animals. The rooms for the hot baths were heated from below by basements which run under the floor, and a number of great furnaces supplied the hot air. Many of the rooms were vaulted, and above these were terraces from which a fine view of the surrounding country could be had.

The city of Tebessa, which is the ancient Roman Theveste, is remarkable for its well-preserved walls. These were built by Solomon, the successor of Belisarius, after the destruction of the city by the Arabs in 535, but as the walls had to be built in haste, owing to the need of defense at that time, they used all the material that came to hand, so that we find stones bearing inscriptions, also moldings or capitals of columns, and even whole columns which are not even cut. The great wall, which will be observed here, has nearly 4,000 feet length in all, and there are fourteen towers erected on it. A four-sided Roman triumphal arch, dating from the time of Caracalla, was utilized to form one of the city gates.

Not far outside the city we find the remains of an ancient monastery, which dates from the early centuries of the Christian era, having been erected probably at the end of the fourth century. As was necessary in those troubled times, it was well fortified by a wall which inclosed all the buildings in a large square space. It still subsisted during the time of the Vandals (439 to 534 A.D.) but as Tabessa was destroyed at this latter date, the monastery was also at least partly destroyed. However, Solomon rebuilt it four years later and in the ensuing period it was found necessary to fortify it well so that it could also serve as an outlying fortress before the city to protect it against frequent attacks. Some parts of the monastery are very well preserved. Passing in at the main gate, we follow an avenue which is still well paved with flagstones. On either side are the different monastery buildings. On one side is the church or basilica which was a handsome structure with marble columns and mosaic inlaid walls and vaulting and richly colored mosaic floor. A large number of cells for the monks are arranged around the outside of the church, being built mainly of stones taken from old Roman tombs. At the end of the avenue is a vast inclosure, which served as stables for the monastery.

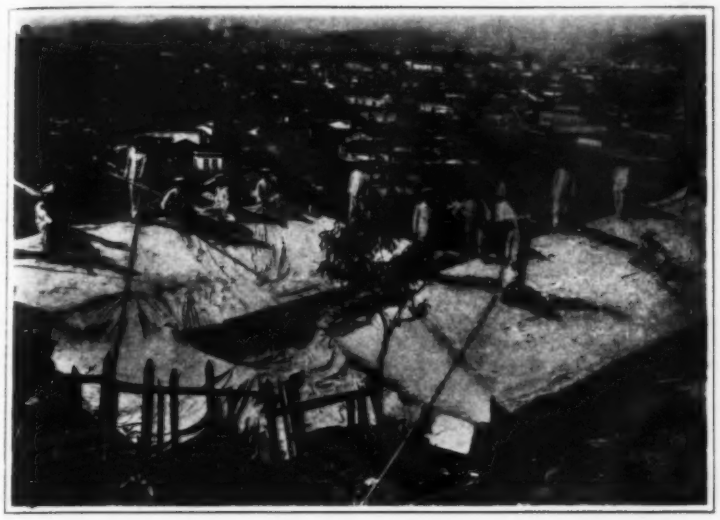
There are two very curious structures found in the African region. One of these is known as the Tomb of the Christians, from the name which the Arabs gave it in early times. It is an imposing mass of pyramid shape, but in this case the pyramid is of circular and conical form. Around the base are sixty Ionic columns and there was probably a statue at the top. No doubt it was erected as a burial monument for the royal family at an ancient period. The Arabs have repeatedly excavated the central part in the hope of finding a treasure, but without success. Very much like the "Christian's tomb" is the structure known as the Medracen, which was probably a mausoleum for the kings of Numidia.

Following an ancient Roman road in the region south of Tunis, we come to the amphitheater of El-Djem. This is remarkable for its great size and imposing appearance, although it lies in such an out of the way region that it is scarcely known. Thysdrus, the ancient

Amphitheater of El Djem—Near View.

city which lay here, was the central point of a flourishing region which is now a desert. The amphitheater was, no doubt, built here in order that the population from all quarters could more easily reach it. The present structure is one of the largest amphitheaters in the world and one of the best preserved. It is built somewhat like the Coliseum at Rome, and is of elliptical shape, with arches around the base and three stories supported on Corinthian columns. In 1710 there were five arches blown up during some local troubles, and since then the breach has been widened, as the Arabs carry off the stones to use them in building their huts.

Interior of Prætorium at Lambessa, With a Collection of Remains Found in Various Places.



Covering Roofs of Houses to be Fumigated.

The Portable Sulphurous Acid Plant.

Stamping Out Yellow Fever in Brazil

A Record of Remarkable Success

By Robert Grimshaw

YELLOW fever, a disease once very prevalent in America, for a long time resisted all attempts on the part of scientific men to discover its pathogenic cause and thus acquire a sound basis of attack in combating the disease. The fever was raging and extracting a heavy death toll at the time the Americans took possession of Cuba. Every effort was made to overcome the disease by means of the ordinary methods of disinfection, etc., known to medical science at the time, but to no avail. Accordingly, a commission of American savants was appointed to make an exhaustive study of the subject of the mode of transmission of yellow fever and its prophylaxis. This commission was composed of Messrs. Walter Reid, James Carroll, Agramonte, Jesse W. Lazear, and M. D. Acting. They called to mind that many years before a Cuban physician named Finlay had suggested the hypothesis that yellow fever was transmitted by the mosquito (*Stegomyia calopus*). Their experiments were therefore directed to test this hypothesis. The results established its truth beyond question, fully disclosing the rôle played by the mosquito in the spread of the fever, and clearly pointing to the remedy to be employed in fighting the terrible pest. All honor to these men of science, who laid the foundations for the systematic subjugation of yellow fever, and, above all, honor to Lazear, who lost his life through devotion to science!

Once the methods had been properly worked out, they were first applied to Havana, with the result that within the space of seven years yellow fever was practically stamped out completely in that city.

The disease had been raging in Rio de Janeiro, the capital of Brazil, with a population of nearly one million inhabitants, since 1850. The Brazilian government had employed every means known in the attempt to suppress the disease, but without result. In 1903 Dr. O. G. Cruz was appointed Director of Public Health. This Brazilian savant, who had previously been Director of the Institute at Manguilhos, reorganized the entire hygienic service of Brazil and introduced a model sanitary regime based on scientific principles. The Brazilian Congress passed laws framed toward the suppression of yellow fever. As is not unusual in such cases, the new measures were at first received with suspicion and were ridiculed by the press, but Dr. Cruz went on serenely and conquered. To-day Brazil recognizes its debt to him, and respects and venerates him above all its countrymen.

In order to stamp out the fever it is necessary to kill all mosquitoes found within a house harboring a person suffering from the disease. It is, of course, eminently desirable to destroy also all larvæ in the breeding places of the mosquito, in the same way as in fighting malaria.

The mode of procedure followed in killing the mosquitoes in an infected house is as follows:

In Rio de Janeiro, as soon as a case of yellow fever is reported, a "sanitary column" is sent with the necessary material for isolating, transporting, and fumigating. The physician determines whether isolation at home is practicable; but as after the third day infection of others is impossible, this is not always necessary. In the house of well-to-do people, where there is a room with one or more doors, and at least one outwardly-opening window, preliminary isolation is affected by a mosquito net with 0.06 inch maximum mesh; the doors are closed quietly so as not to drive out the mosquitoes present. The window openings are closed with wire netting, but in such manner that the shutters may be opened and closed. A vestibule is built on the main entrance, with two wire-net doors which can not be opened simultaneously. Any cracks in doors, windows, or walls are closed by pasting paper over them. The room is fumigated with *pyrethrum* before the patient is brought in; in the meantime the entire house is similarly fumigated. The roof is covered with sail cloth; chimney and ventilating flues are closed above; furniture is taken apart and cleaned, to ferret out all mosquitoes and is then set up at some distance from the wall in order to facilitate the fumigation.

Heavy metal parts are greased to prevent damage by the sulphur fumes; other objects are protected by paper or cloth. Where there are no articles likely to be injured by sulphur this is used, otherwise, *pyrethrum* is employed. To catch the stupefied mosquitoes which must be burned, pictures, mirrors, etc., are covered with slanting paper sheets. For fumigation, which should be continued for one-half hour, 10 grammes of sulphur per cubic meter are necessary for well-closed rooms; otherwise up to 20 grammes. The patient must of course not be exposed to these fumes. Of *pyrethrum*, 10 to 15 grammes are required, the rooms being kept closed for two and a half to three hours. Then the shutters are opened, all rooms swept clear, the paper strips removed, and sweeping and paper burned.

The roof gutters are cleaned out and the water tanks closed air-tight with paper strips. Sulphurous acid gas is blown through the sewers; any puddles are covered with petroleum, and ponds which are full of larvæ are stocked with *Girardinus caudi maculatus*, a little fish which hunts and devours this particular "small game."

To prevent their development, mosquito larvæ then are hunted in every quarter of the city—in houses, gardens, abandoned lots, etc., where there is stagnant water, or where there are reservoirs containing water, in which the mosquitoes could develop. If the water is in a district where it can not be got rid of, petroleum is poured upon it. Reservoirs are closed and hermetically sealed with paper strips.

Ponds or small reservoirs of water found in gardens are stocked with the little fish mentioned above. All brooks are cleaned out to insure a constant flow of water for under these conditions the development of the mosquito is impossible.

The results obtained at Rio de Janeiro have been most admirable: as may be seen by reference to the following official figures:

Year.	Deaths.
1902	984
1903	584
1904	48
1905	289
1906	42
1907	39
1908	4
1909	0
1910	0

The same methods have been employed in several cities in the State of Sao Paulo, and the results have been the same: that is, the yellow fever has disappeared from every town where the prophylactic methods have been applied.

Quite recently, Dr. Oswaldo Cruz was charged by the government of the State of Para to make a similar crusade in the city of Belém, the capital of that State. He accepted the task, and inaugurated the service in November 1910.

The number of recent deaths in Bélem, as compared with those of previous years, may be seen below:

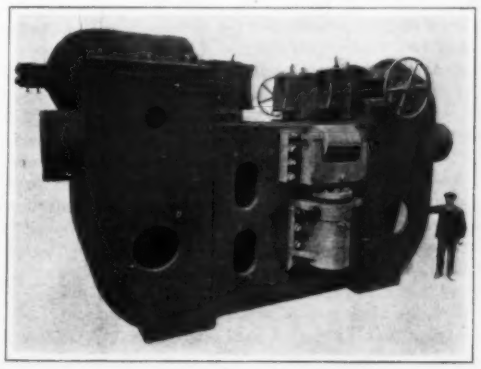
Month.	Deaths.
November, 1910	49
December, 1910	37
January, 1911	15
February, 1911	9
March, 1911	4
April, 1911	0

That is, in five months, yellow fever has been completely banished from Bélem—a city of about 350,000 inhabitants.

In recognition of his services, the Brazilian government has named the institute at Manguinhos after Dr. Cruz, and to-day this "Oswaldo Cruz Institute" is the pride of medical science in our young sister republic.

Horizontal Gun-Straightening Machine

A LARGE horizontal gun-straightening machine has been recently constructed by Fielding and Platt, Limited, Gloucester. This firm is often called upon to design adaptations of its well-known Tweddell's system hydraulic machine tools for special purposes, and the present example, of which we give an engraving below, reproduced from *The Engineer*, has been made for an Italian shipyard. It is capable of exerting a power of 2,500 tons on the main ram with intensified pressure, and for lighter work it is so arranged that a pressure



Machine with Gun in Position.

of 565 tons can also be obtained for work on smaller forgings, direct from the accumulator.

The machine, as will be observed, is of exceedingly massive design. To give some idea of its size it may be mentioned that it weighs 195 tons, and that the total weight of the contract, which included pumps, accumulator, etc., was 220 tons. The press, the main frame of which is of best cast steel, is fitted with an intensifier and water-saving gear, in addition to which the makers supplied a set of three-throw electric motor-driven hydraulic pumps for working the press at its full capacity, with a tramway type motor controller operated automatically, as well as an hydraulic accumulator.

Finger Prints*

A Chapter in the History of Their Use for Personal Identification

By Henry Faulds

THE famous Tichborne case gave a great impulse to the study of identification as a question in jurisprudence. I was leaving this country for Japan in 1873 and the vast crowd around the old Court at Westminster impressed me greatly with the importance of the subject. Craniology seemed to many to have had its day, and the complexities of constantly varying methods had induced almost complete skepticism. If a race could not be distinguished on anatomical grounds, how could we ever hope to identify a single member of the human family on the basis of anatomy with confidence and precision? It had been decreed, *nemine contradicente*, except Virchow—an important exception—that all the soft tissues, hair, skin, and the like, were now useless for such a purpose. I had studied photographs most carefully, but found them to be traitorous, the same people being made to look quite different in a changed light, by another mode of developing, with the varying psychological moods of the sitter. They were useful but not precise. After certain illnesses, too, the living face was found to change, as in typhoid fever, and more temporarily in ague. The tragic effects of small-pox are well known to novel readers. Our police in England used not long ago to keep an indexed record of tattoo-marked persons who had once been convicted. I doubt if they ever had a case like that of a Japanese once employed by me in their collection. This man's case was unique, I think, his whole skin surface being one finely-wrought pattern, not only intricate but really beautiful. Now such a case might be copied, at great trouble and expense, to win a fine estate. But no one can produce to order the simplest finger-print pattern in living tissue. It may be destroyed, whereas, on the other hand, a complex tattoo pattern can be created but can hardly be destroyed. Sir Edward Henry says of finger-patterns that they are out of all proportion more numerous than such measurable features as tattoo marks, but I think he cannot have contemplated such cases as that just described.

Along the great populous beach of the Bay of Yedo, where the hospital was which I had charge of, were many shell-heaps or kitchen middens. Some of them were ancient, while others had an almost unbroken history coming down to our own day. Amid the oldest heaps I often found fragments of sun-baked pottery, on which finger-marks had been impressed when the clay was soft. These seemed to have been made by children, perhaps young girls, whose ancient fingers had dinted the edges of the soft ware as pie-crusts are still molded by the thumb of baker or pastry-cook. Similar articles were then (1878) made and sold as toys, and I purchased many of them in the bazaars of Tokyo. Ancient ware, baked in the sun but never fired, and marked with finger furrows, is in high repute for the ceremonial tea-drinking of Japan, but it is quite incorrect to say, as has been said and written, that no other is ever used in those depressing festivities. Sometimes the furrows or ridges of those ancient finger-marks came out sharp and clear, but much oftener they were blurred or smudged by movement during the act of impressing. In the modern toys, however, the imprints were better impressed and were obviously intended for ornament. Endowed, or afflicted, with myopic eyes, I was led very early to notice how, in the modern ware, one peculiar pattern of lineations would reappear with great persistency, as if the same artist had again left her sign-mark on her work.

I examined directly many thousands of living fingers, then passed on to consider impresses on putty, bees-wax, sealing-wax, clay, and other substances, taken from my own fingers, those of students under my care, and medical men, native and foreign, and out-patients who might visit the hospital. These were at first very roughly classified and analyzed. I am quite sure that at this point the conception of a wide and general method of identification flashed upon me with suddenness. Almost immediately followed a most depressing sense of moral responsibility and danger. What if someone were wrongly identified and made even to suffer innocently through a defective method? It seemed to me that a great deal had to be done before publicly proposing the adoption of such a scheme. Till then we had used wax and other plastic substances (and on the whole, paraffin was found to be best) but now I remembered lessons on botany I received in Anderson's College, Glasgow, as a lad attending to business. We used to print the leaves collected in Saturday afternoon excursions with an oily mixture of burnt cork. Using good printing ink in Japan, then, we got large numbers of clear and excellent finger impressions. Their variety was wonderful, and we could study details with much greater ease and delicacy than in *relievo* impressions. From that stage onward I made steady observations, seeking specially to determine whether the patterns characteristic of one individual ever varied from time to time, either in general arrangement or in linear detail. At this time I had noticed that the pigment in human freckles and in the skin affection called *leucoderma* (supposed by some to be the "white leprosy" of the Hebrews) migrated, as my teacher, Lord Lister, had shown to be the fact with the pigment on a frog's foot. The mode I took to test whether the ridges ever shifted their situation or changed their form was by shaving away their elevations or rubbing them down with various powders to smoothness, having first taken careful imprints of the patterns. After the skin grew up again fresh imprints were taken and compared with the old ones. These were scrutinized very carefully for changes, but in many hundreds of cases, tested thus three or four times, not one solitary example of a variation in pattern was detected.

Fig. 1.—Enlarged Finger-Print Showing Sweat Pores.

The patterns always came up with perfect fidelity to the old standard. Arrangements were made for a still more extensive test extending also over a greater period, but exhausting illness from climate and overwork caused my return to England, and broke for a time the thread of my investigations. I returned to Japan after a rest, but had again to come back to England in 1886. The firm conviction, however, was established in my mind, which nothing has occurred to change, that skin furrows for the purposes of identification are invariable throughout adult life. Observations of select cases from that period—thirty-two years ago—till now have been made from time to time only to confirm my early results. Fig. 1 is one of my earliest prints. In fourteen years it had not changed in the living person. From time to time I have watched cases of fever, and have drawn medical attention to the subject, thinking the great activity of the skin shown by peeling or desquamation might be accompanied with some changes of pattern, but no case has yet been observed by myself or recorded by others so far as known to me. The subject of classification now presented itself. Those who talk glibly about comparing a single "thumb print"—the favorite digit—with, say, four millions of single finger prints, do not seem, as a rule, to perceive the difficulty. It seemed that a good system should be able to face such numbers. Five years of my early life had been spent in learning a trade—that of Paisley shawl manufacture—which almost vanished before the end of my time. It seemed to have been an utterly wasted time, leading to nothing and helping no one; but it had drummed into my dull head how to deal with patterns. What I intend to convey by a pattern in finger prints may best be understood by looking at a few enlarged diagrams of the central or most characteristic portion of the *rugæ*, or skin-ridges, with their complementary furrows or *sulci*, which are found running over the sole of the foot (*planta*), the palm of the hand (*vola*), and front or palmar surface of the fingers. Indeed, they are even found in the prehensile tail of the spider-monkey, as in the diagram. (See Fig. 2—spider-monkey's tail.) Near the middle of the last joint of each finger there are usually lineations in the skin of much complexity, which form the basis of identification by finger prints. (See Fig. 3).

Fig. 2. — *Rugæ* or ridges on the under surface of the prehensile tail of *Ateles ater* (Spider Monkey).

Fig. 4.—Smudge from a finger. A typical example of the general appearance, in natural size.

Without going into details, which would require a wealth of illustrative figures and would probably interest but a few, it may be explained that my system proceeds on the conception that an elementary pattern is like a character in a foreign fount of type. So the classification is that of a syllabic dictionary, each syllable standing for a single finger-pattern as a Chinese character is printed in many dictionaries, and as Japanese is now printed. Each vowel may be a syllable in this sense, but no consonant stands alone, and the vowels associated with consonants always preserve their original pattern significance. The consonants go in related pairs, as t, d; p, b; f, v; s, z; l, r; m, n; k, g. The elements that compose patterns of any complexity are similarly related in pairs, and thus the association of sound and sense soon becomes complete in the mind of the dactylographer. But the syllable, after all, only denotes a class which may contain several—usually not a great many—individuals, all differing in minute details. With my system the whole strain of the original translation into the finger-print vocabulary, which is never great, lies upon the shoulders of one or perhaps two experts, but all the rest of the work can be done by any schoolboy who can turn up a word in a dictionary. To give an example offered to the War Office Committee by me when being examined as a witness; the expert, reading off a new set of say five finger-prints in one hand which has come in, calls for all old records filed past containing *Abracadabra* (a fanciful word of five syllables). That word in syllabic form might read

A–bra–ca–da–bra, or
Ab–rac–ad–ab–ra, or
Ab–ra–cad–a–bra, and so on.

Under any of these forms there might be several people indicated. But it would be found that only one, if any, would correspond exactly with the person to be identified. At all events, that is the belief, not easily to be shaken, of some hundreds of experts working for now about a decade, in different countries. This means quite an extraordinary security, beyond anything hitherto conceived, in regard to personal identification, but its efficiency does not depend on any one method of classification.

On February 15th, 1880, I wrote to Charles Darwin, sending specimens of prints and an outline of my first results, and requesting him to aid me in obtaining access to imprints from lemurs, monkeys and anthropoids, as I had found them to show lineation patterns which I hoped might be serviceable for the elucidation of man's lineage. I had failed to find any trace of previous notices of the subject in anatomical or recent biological works. The great naturalist's reply, two years before his death, was as follows:

Via BRINDISI,
April 7th, 1880.

DOWN,
BECKENHAM, KENT,
RAILWAY STATION,
ORPINGTON, S.E.R.

DEAR SIR: The subject to which you refer in your letter of February 15th, seems to me a curious one which may turn out interesting; but I am sorry to say that I am most unfortunately situated for offering you any assistance. I live in the country and from weak health seldom see anyone. I will, however, forward your letter to Mr. F. Galton, who is the most likely man that I can think of to take up the subject to make further enquiries.

Wishing you success,
I remain, dear Sir,
Yours faithfully,
(Signed) CHARLES DARWIN.

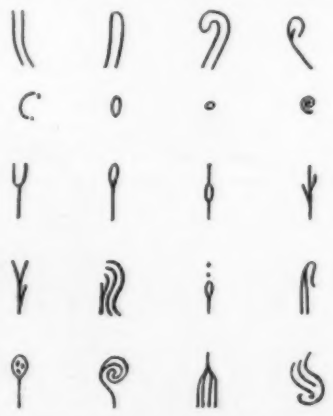


Fig. 3.—Skin Lineations (diagrammatic).

* Reprinted from *Knowledge*.

The original of the above holograph letter, with envelope addressed by Mr. Darwin and duly postmarked, along with the proof sheet of the first copper-plate form to receive finger-prints, made for me in Japan, is now in the Library of the Royal Faculty of Physicians and Surgeons, Glasgow. On October 28th, in *Nature*, appeared a contribution by me, "On the Skin-furrows of the Hand," which was printed in the *Index Medicus* of the United States as the first recorded contribution on that subject. At the International Medical Congress, about ten months afterward, Dr. Billings, then editor of the *Index*, said, in a speech: "Just as each individual is in some respects peculiar and unique, so that even the minute ridges and furrows at the end of his fore-fingers differ from those of all other forefingers, and are sufficient to identify," and so on. (Report in *The Times*, August 5th, 1881.) My proposal was certainly the first public suggestion to establish a scientific method of identification on the basis of finger-prints. Sir William Herschel wrote soon afterward to *Nature*, admitting my priority of publication, but stating that he had used a method of finger-prints in India before this. There is no dispute between Sir William Herschel and myself, as each had reached his own conclusions quite independently. This little personal matter was discussed in *Nature* (October, 1894) and in *Gegenbauer's Jahrbuch* for 1905, in which the date of my first contribution is considered the starting-point of recent study of the subject. In 1881, Monsieur Bertillon, of Paris, brought out his delicate anthropometric system, to which the independent finger-print method from England was superadded. The finger-print method alone was used in a United States expedition in 1882, and it was tried in San Francisco, as afterward in South Africa, to identify the fluctuating population of Chinamen. In the year after my final return to England greatly renewed interest was aroused in the subject. Herbert Spencer tried to explain the origin of the ridges in an article in *The Nineteenth Century*, May, 1886. Sir Francis Galton, to whom Charles Darwin wrote to me in 1880 that he would refer the matter, began the study, as he states on page 2 of "Finger Prints," in 1888. In that same year, Inspector Tunbridge from Scotland Yard was officially appointed to investigate my proposals. No report has ever been made public, but Mr. Tunbridge told me that he feared the method was too fine to work, and said that nothing could be done, at least without fresh legislation. Some years afterward he was appointed to New Zealand, where he was the means of inducing the prison authorities and police to apply the method, which has been now in successful operation all over Australasia for some years; so Mr. Tunbridge wrote to me in 1907.

In 1894, a committee appointed by Mr. Asquith met and finally, after some rambling conclusions, adopted Bertillonage with finger-prints as some help, the former being used as the basis of classification. The proposal was absurd, and it was soon found, as might have been foreseen, that finger-print patterns yield a far firmer and more searching basis of classification in themselves than the other method, and need no auxiliary crutches.

In 1897, the two associated methods began to be applied in British India; while in civil cases there, as in attestations, pension claims, and so on, the finger-print method was used by itself.

In 1901, the ten-finger method in serial order, exactly as originally advocated by me in 1880, was finally adopted in England, after other trials, and has met with an immediate and triumphant success in giving rapid and easy identifications of recidivists or old professional criminals, often living under aliases. Monsieur Bertillon, who at first did not use finger-prints at all, wrote to me officially that since 1894 the two methods had been jointly used in Paris, and that greater security was now felt in identifying. In 1902, finger-prints took the place of bodily measurements in Austria-Hungary, being easier of application, and less likely to give varying results. Two years afterward Spain followed suit. The method had been worked before that period in Buenos Aires with success. A private service for identification by the finger-print method was, I believe, instituted in Belgium by Dr. de Laveleye, but I have heard no report of results.

It is a curious fact, but true beyond question, that the effectiveness of the method has proved to be the chief obstacle to its more extensive application. In short, its miraculous effect in tearing the mask from old criminals who try to veil their identity by an *alias*, has created a horror of it among the class from which many recruits used to be drawn for army and navy.

In conclusion, I should like to point out that there are five distinct ways in which Dactylography, as the scientific study of finger furrows is called, may be serviceable:

(1) In relation to the problem of human lineage. Much tentative work has been now done in this field by many workers, and a scientific pathway begins to open up before us.

(2) In elucidating the relations of front and hind limbs; Prof. Bowditch, of Harvard, wrote to me that he had early begun an inquiry into this subject. It promises to yield results of interest, but more workers are required.

(3) In identifying for life insurance, pensions, passports, affidavits, cheques, signing deeds, and so on. Again, in identifying the dead by former records, after battle, flood, fire or earthquake.

(4) In identifying old convicted criminals who have assumed other names.

(5) In testing evidence of bodily presence at a scene of crime by bloody finger-marks, sweaty or greasy smears on glass windows, wine glasses, lamps, or cash boxes and the like, or indented impressions on putty, wax, paraffin and so on. Faint impresses can be revived; invisible ones quite clearly brought out by chemical means; imprints *in relievo* may be photographed and made clearly intelligible to a jury. (See Fig. 4—a smudge from a finger.)

The last, and I think by far the least, of these once potential, now actual, utilities has taken the deepest hold of the popular imagination, and has seemed, to me at least, to threaten some danger to the innocent by its often ignorant and unscientific application. The method is not "mathematical," as certain officials are never tired of repeating, but demands common sense and the use of their own eyesight and mother wit by the plain men in the jury box. It is essentially English, and every accused person in the dock is as able as a judge, or counsel, or official witness, to test its validity.

The Genesis of the Rare Earths*

Their Relation to the Earth's Past History

By Dr. R. Böhm

IN spite of the large monazite sand deposits in Brazil, the total quantity of all the rare earths probably does not exceed all told 1/1,000,000 per cent of the entire crust of the earth. When the latter was still in a heated state, composed of a mixture of all the elements, the atoms probably united to form the principal components of the earth's crust. In that condition the rocks formed gradually and slowly, taking their origin from those materials which were most widely and largely scattered throughout the mass, and in this way the granites, quartzes, the gneisses, the feldspars and the micas came into existence. These crystalline formations grew denser and denser, drifted into each other and were raised high up into mountain ranges of gneiss, granite and other primary rocks. The other component parts of the magma of the earth could not keep pace with the growth of the more common and larger kinds of rocks. They had to search too long for their chemical affinities. Auer von Welsbach in his experiments with the salts of thorium, was able to prove an enrichment or concentration of the traces of cerium, which had been present in the thorium in the mother lye, and thus the less or least largely represented ingredients of the fluid magma, which here represented the mother lye of the crystalline formation, were concentrated. Then began a process of selective crystallization, during which the rarer ores and minerals, for whose recovery we are now digging and searching through the primitive rocks, were formed. Thus the shining particles of gold passed into quartz, and the modest little dark crystals of monazites, thorites, gadolinites, euxenites, and other derivatives of the rare earths were saturating the granite. However small their dissemination in the magma may have been, in the end like aggregated with like, and the rare earths were safely imprisoned in the grasp of the powerful giant granite. But at this time another younger and still more powerful giant appeared upon the scene and began to fight an obstinate war with granite, which lasted millions of years. This young giant was the water. Without rest or interruption, swift and mobile, yet fighting with untiring perseverance, he renewed his attacks on the old granite again and again, and though his advances were but slow, he always remained victorious, and every year his armies, the rivers and rivulets, carried all the loose material which the granite held imprisoned, down into the valleys. Among those that were freed by the water were also the minerals of the rare earths, and every once in a while some of them would bid farewell to their old prison and migrate in company with the quartzes and feldspars, whose numbers were so great that the stranger quite disappeared among them. But when we bear in mind the long ages during which these forces have been working, it becomes plain that gradually quantities of rare earths, which for us seem immense, must have been washed into the sedimentary rocks. But though large in themselves, these quantities, compared with the thousands of millions of tons of solid matter which finely ground covered the crust of the earth, seem very small. The rare earths were in fact as finely disseminated as before, and any possibility of finding them and proving their occurrence seemed to be out of question.

And yet it was possible to find again what seemed to be lost forever. The organic power of nature found it possible to enrich the infinitely small traces of rare earths in the surface soil, so that it has been found within our means to prove their occurrence. Just as sea weed attracts and accumulates the infinitesimal particles of iodine in the sea water, so the plants' hunger for mineral substances has concentrated the salts of the rare earths and absorbed them as parts of the organic structure of the plants, using the decomposing faculty of the roots as an agent. Cossa, the Italian physiologist, has been able to prove that the rare earths, especially the cerite earths, are present in very small quantities in the ashes of plants and bones. This is the end of nature's organic reduction process and in this way the very rare minerals cerite, thorite, and monazite have been found in the sand strata of very great thickness in Brazil, Australia, North America, and the Ural Mountains, where nature has eliminated and deposited the heavy monazite sands from the corrosion and decomposition products of the rocks. The monazite sand is also associated with gold, an occurrence which finds an easy explanation in what has been said above. The gold districts of Carolina contained wash drifts of the mountain rivers, showing a sand which consists mainly of brown or yellowish brown crystals. This so-called monazite sand had already attracted the attention of the miners, at a time when gold washing was in full swing, by its heavy weight, but it had been thrown aside as worthless until the genius of Auer von Welsbach recognized its real value.

The commercially important monazite sand deposits lie in the alluvial detritus of the rivers and their sub-soils, as well as in the sand deposits along the sea coast. Such deposits could only have been formed in countries which remained immune from the erosive action of prehistoric glaciers. The latter at one time covered a large portion of the earth's surface, especially in the northern hemisphere. In the countries lying outside of the limits of these prehistoric glaciers, the soft surface layer of the decomposed rocks remained in their original position, excepting, of course, the changes caused by the action of the running water. These surface layers of detritus (also called saprolith, i. e., rock decomposed but not washed away) often reach a thickness of 50 to 200 feet. Owing to water erosion these saproliths have been further broken up, and were carried down into the river beds and their sub-soils. There the material is subjected to a further natural eliminating and concentrating process, the heavy matter being deposited first. Wherever the saproliths carried monazite, this mineral has, owing to its great specific weight, accumulated together with other minerals such as titanium-oxide, granite, feldspar, and quartzite. The process by which sandbanks are deposited in the sea is similar in nature. Sea waves, when breaking against monazite-bearing, crystalline sands, loosen the latter, and, washing away the less heavy earths and minerals, leave along the coast concentrated deposits of monazite sands, mixed with greater or less quantities of other minerals.

To-day the designation "rare earths" hardly has the same meaning it had a little while ago, especially, at the time when the incandescent gas light, in whose production some of the rare earths play an important part, was first invented. At present we are acquainted with about one hundred minerals containing rare earths. But, of course, when we compare them in quantity with other kinds of earths, we can still give them the designation "rare earths," even though their quantity and number is considerable.

* Abridged from the *Zeitschrift für angewandte Chemie*.

AT the beginning of 1910 the United States, where there is no State telephone monopoly, had 7,000,000 telephones for a population of 80,000,000, or 87 telephones for 1,000 inhabitants.—*The Engineer*.

Fig. 1.—Sorting the Horsehair Over Suction Screens.

Fig. 2.—Mixing Various Kinds of Hair Together.

Horse Hair*

A Glimpse of the Zoological Side of Commerce

By Hubert H. Poole and Wilfred Mark Webb

THE part which animal products play in our everyday life is very important indeed, and many of them go through very elaborate processes of preparation. The whole subject is attractive, and especially so in the cases where there is no possibility of the creatures most directly concerned being ruthlessly exterminated. It will have a special attraction for the specialist who deals with the groups to which the animals in question belong.

Fig. 3.—The Careful Untwisting of the Rope After Steaming and Drying.

Mammals are at one end of the scale of zoology, and their most characteristic external feature is the presence of hairs. Indeed, there is practically no member of the class which does not produce hair at one stage or another of its existence. That of the horse is especially well developed on the neck and tail, proving ornamental in both instances, but in the latter also useful for brushing away flies, which often are a great source of irritation.

The horse-hair used for commercial purposes arrives in bales up to half a ton in weight, and a hundred and twenty pounds ($587) in value. The chief sources of supply, according to *Knowledge*, are Great Britain, North and South America, Australia, Germany, Russia, and China. The tails are the best, because the hairs are hard, the manes being soft and therefore of inferior value. The specially long hairs are, of course, suitable for particular purposes, but we will deal first of all with those of ordinary length, which are to be prepared for stuffing furniture, and no one who has not seen the process would imagine how elaborate this is.

The hair is first sorted over suction screens (see Fig. 1), which draw out the dust and carry it away. Color forms the first basis of classification, black, white and gray hair being distinguished, and after this the hair is divided up according to its various lengths and its quality. That which is to appear black is dyed in log-wood, washed and dried, and then, as is shown in Fig. 2, the various hairs are mixed together on the floor so as to make stuffings of different prices. After this the material is passed through a series of mixing machines or mills, which are provided with exhausts for taking out any dust which remains.

Now comes the most curious part of the process. A short walk is provided something similar to that on which hempen cords are made and here the hair is twisted up to form ropes. Each pair of workmen is followed by a boy who beats up a fresh supply of material and that which is dropped, with two sticks, thus getting it ready for the use of the twisters. The ropes are again twisted upon themselves, soaked for two hours in water, then baked at a temperature of upwards of 350 deg. F. for twelve hours. The damp heat, as may be well imagined, destroys all bacterial life that might possibly exist in the hair, and at the same time fixes the curl. The ropes (see Fig. 5) are hung up to cool for three days. The low qualities are then untwisted and carded by machinery, though this process is liable to break the staple (see Fig. 6). The good qualities are opened out (see Fig. 3) and hand carded, the opened twists being placed on the bent pins of the carder which give somewhat as they are fixed into leather that is in turn fastened to a board.

The hand carding process is shown in Fig. 4, and finished horse-hair is to be seen in the background.

Fig. 4.—Hand Carding the Untwisted Horsehair from the Ropes.

The finer the quality the smaller the rope and tighter its coils. The hair from English cart horses is the best, because it is the strongest, and for the highest qualities, long hairs are used. The very finest grades cost up to seven shillings per pound wholesale. Black hair is usually somewhat stronger than the white, but

Fig. 5.—Horsehair Ropes Hanging Up to Dry.

Fig. 6.—Untwisting and Carding the Ropes by Machinery.

* Reprinted from *Knowledge*.

Fig. 7.—Wet Hackling the Long Hairs Which Are Not Used for Stuffing Purposes.

Fig. 8.—Drawing Out the Hairs and Sorting Them Into Various Lengths.

Queen Victoria, who was very partial to horse-hair mattresses, always had the best quality of white hair. As it takes about forty pounds of hair to make a full sized mattress, it will be seen that the cost is somewhat considerable.

One man in the employ of Messrs. William List & Sons, who very kindly gave facilities for this article to be written, can boast of over sixty years' service, while several can claim over forty. The men train their sons, as a long experience is necessary in nearly all the processes.

Messrs. List get the longest tails from China and Russia. These are disinfected before they are handled, as a precaution, and after being dipped in a bath of soft soap and soda, are wet hackled (see Fig. 7) to get out all the short fur. The sorted hairs are dry carded, being piled up on a board which is studded with long pins and drawn from the two ends between an old razor and the thumb to lengths down to five inches (see Fig. 8).

White hair which is thirty inches long and upward is used for violin bows. This is exported largely to Germany by Messrs. List. Black hair, which as we have said before is slightly stronger, is used for the bows for double basses. Shorter hair, according to its length, is tied in bundles and sold to brush makers or to plume makers, for whom it is dyed various colors for ornamenting helmets and the bridles of cavalry horses.

A more extensive use of the long hair is for weaving it into seatings in which a linen warp is used, while the hair cloth which tailors employ for stiffening garments where elasticity is required is made with a warp of cotton. The widths vary from sixteen to thirty-four inches, and it may be pointed out that to produce a thirty-four-inch cloth the hair must be thirty-eight inches long. Some of the hair is of exceptional length, and one tail in an extreme case which passed through Messrs. List's hands measured seventy-two inches. The brown hair is used for fishing lines and was much in vogue years ago for cod fishing. One advantage of the old method was that only healthy fish were caught, while now, it stands to reason, the trawls will bring up all that come in their way, whether they are in good condition or not.

Wigs for judges and barristers are made from what is known as "dead" hair which has no glint upon it, and is specially picked out for the purpose.

The hair from the tails of cows and oxen is also used for one or two purposes. The ends of the tails themselves are brought over attached to the skins and always show a twist. This with the very rarest of exceptions is in one direction. The cow tails are dressed whole and undyed (as are sometimes horse tails from South America), for export to South Africa, where they are used for personal adornment by the natives. The latter insist on the hair being undyed, and they plait it into bracelets and over gourds used for snuff, as well as combine it with the wire which is put over sjamboks and sticks. They also use it for threading beads. North American Indians use dyed hair for the same purpose, and for weaving into their moccasins.

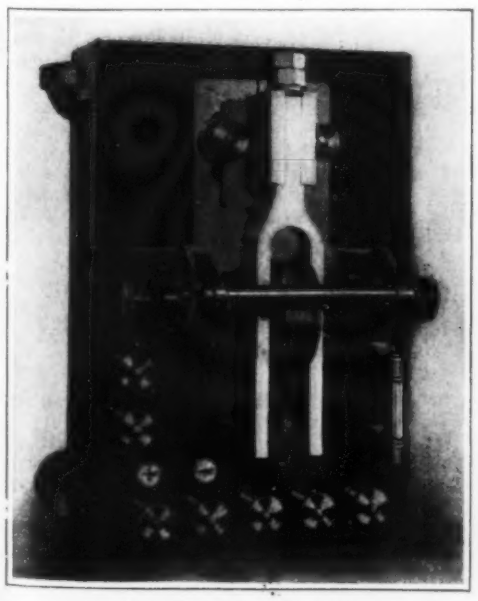
The cow hair is also drawn for weaving into sieve bottoms to form strainers for cooks and gun-powder manufacturers, while horse-hair bags are used for oil and cider presses and for brewers' straining-cloths.

Lastly, goats' hair from China and Tibet, being very soft, is used for babies' brushes.

The Mercadier-Magunna System of Telegraphy

An Improved Method of Multiplex Working

It would seem natural that inventors should long ago have solved the problem of high speed telegraphy, from the fact that this is needed in order to keep pace with the rapidly increasing traffic upon the telegraph lines. A single wire should be made to carry a much greater number of messages than in the earlier days when the demands upon the lines were not as great as they are now. One way to do this is by using some kind of rapid telegraphy method; another is to employ a multiplex system so as to send a number of messages over the wire at the same time. We hear from time to time of very ingenious rapid telegraphy instruments which should greatly increase the speed of sending messages, but the fact that the old instruments are still in use appears to prove that the new high speed methods are not well adapted for practical purposes. This is especially true where photographic processes are used for receiving. As to the other method which consists in sending a large number of messages at once over the same wire, no practical invention appears to be in the field, for in America we find the old Edison duplex still holding the ground. In Europe, printing telegraphs are largely used, and they give a very good speed; for instance, the Baudot printing telegraph has been used as a standard in France for many years past, and it can be operated as a quadruplex, that is, sending two messages each way upon the line. Each message gives 1,550 words per minute, so that we have thus 6,200 words per minute over a single wire.



The Tuning-Fork Transmitter.

We wish to speak of a new method of multiplex telegraphy which is devised by Prof. Mercadier, the well-known Paris scientist, and M. H. Magunna, a leading engineer, who has had great experience in telegraph matters. It is very carefully worked out so that it can be applied to the usual telegraph lines without making any change in the standard instruments or the line, and in this respect it has great advantages. All that is done is to add a greater number of the usual instruments, such as Morse sounders or printing telegraphs. That is, where we now use two sounders on the Edison duplex, six other sounders can be added, making eight instruments in all.

We have already mentioned the principle which Prof. Mercadier proposed a number of years ago for multiplex telegraphy. It consists in the use of vibratory currents on the line in place of the usual direct current. Such currents are produced by tuning fork instruments of special design. To illustrate the principle we may suppose that we have a tuning fork which gives the note *d* and a second fork of the note *a*. We mount these at one end of a table and at the other end we have two similar forks. Striking the *d* fork, we note that the sound waves which it sets up will affect the like fork at the other end and it will sound somewhat faintly, while the *a* fork remains silent. The reverse also holds good, so that each fork will respond only to the proper vibration. But if both forks are struck, both the others will respond and each selects out its proper waves and is acted upon by them and by no others.

Exactly the same principle is used in the Mercadier-Magunna system, except that each fork is vibrated by placing an electro-magnet between the prongs in the usual way so as to make and break the contact for a battery current. Such an electro-magnetic tuning fork will keep on vibrating as long as the battery current is put on. However, the varying magnetic flux, which is set up in the electro-magnet by the vibration of the steel fork, also gives rise to alternating currents, and these can be sent out upon a telegraph line. Such currents have a pitch which is exactly the same as the vibration pitch of the fork, for instance, 500 vibrations or periods per second. At the other station is an identical fork whose electro-magnet receives the current and this causes the fork to vibrate. As above shown, two or more forks can be mounted in a selective system on the same wire. The current from all the forks can be sent out on the line without interfering and each is received in the proper instrument at the far end. To send two messages at once, for instance, it only remains to use a Morse telegraph key with each sending fork so as to make dot and dash signals, not as usual with direct current, but with the vibratory current. As this current has a high pitch, from 500 to 900 periods per second, no difference is found in sending the signals. Each operator sends his message independently and all the waves pass over the

The Selective Receiver.

Fig. 1.—Sorting the Horsehair Over Suction Screens.

Fig. 2.—Mixing Various Kinds of Hair Together.

Horse Hair*

A Glimpse of the Zoological Side of Commerce

By Hubert H. Poole and Wilfred Mark Webb

THE part which animal products play in our everyday life is very important indeed, and many of them go through very elaborate processes of preparation. The whole subject is attractive, and especially so in the cases where there is no possibility of the creatures most directly concerned being ruthlessly exterminated. It will have a special attraction for the specialist who deals with the groups to which the animals in question belong.

Fig. 3.—The Careful Untwisting of the Rope After Steaming and Drying.

Mammals are at one end of the scale of zoology, and their most characteristic external feature is the presence of hairs. Indeed, there is practically no member of the class which does not produce hair at one stage or another of its existence. That of the horse is especially well developed on the neck and tail, proving ornamental in both instances, but in the latter also useful for brushing away flies, which often are a great source of irritation.

The horse-hair used for commercial purposes arrives in bales up to half a ton in weight, and a hundred and twenty pounds ($587) in value. The chief sources of supply, according to *Knowledge*, are Great Britain, North and South America, Australia, Germany, Russia, and China. The tails are the best, because the hairs are hard, the manes being soft and therefore of inferior value. The specially long hairs are, of course, suitable for particular purposes, but we will deal first of all with those of ordinary length, which are to be prepared for stuffing furniture, and no one who has not seen the process would imagine how elaborate this is.

The hair is first sorted over suction screens (see Fig. 1), which draw out the dust and carry it away. Color forms the first basis of classification, black, white and gray hair being distinguished, and after this the hair is divided up according to its various lengths and its quality. That which is to appear black is dyed in log-wood, washed and dried, and then, as is shown in Fig. 2, the various hairs are mixed together on the floor so as to make stuffings of different prices. After this the material is passed through a series of mixing machines or mills, which are provided with exhausts for taking out any dust which remains.

Now comes the most curious part of the process. A short walk is provided something similar to that on which hempen cords are made and here the hair is twisted up to form ropes. Each pair of workmen is followed by a boy who beats up a fresh supply of material and that which is dropped, with two sticks, thus getting it ready for the use of the twisters. The ropes are again twisted upon themselves, soaked for two hours in water, then baked at a temperature of upwards of 350 deg. F. for twelve hours. The damp heat, as may be well imagined, destroys all bacterial life that might possibly exist in the hair, and at the same time fixes the curl. The ropes (see Fig. 5) are hung up to cool for three days. The low qualities are then untwisted and carded by machinery, though this process is liable to break the staple (see Fig. 6). The good qualities are opened out (see Fig. 3) and hand carded, the opened twists being placed on the bent pins of the carder which give somewhat as they are fixed into leather that is in turn fastened to a board.

The hand carding process is shown in Fig. 4, and finished horse-hair is to be seen in the background.

Fig. 4.—Hand Carding the Untwisted Horsehair from the Ropes.

The finer the quality the smaller the rope and tighter its coils. The hair from English cart horses is the best, because it is the strongest, and for the highest qualities, long hairs are used. The very finest grades cost up to seven shillings per pound wholesale. Black hair is usually somewhat stronger than the white, but

Fig. 5.—Horsehair Ropes Hanging Up to Dry.

Fig. 6.—Untwisting and Carding the Ropes by Machinery.

* Reprinted from *Knowledge*.

Fig. 7.—Wet Hackling the Long Hairs Which Are Not Used for Stuffing Purposes.

Fig. 8.—Drawing Out the Hairs and Sorting Them Into Various Lengths.

Queen Victoria, who was very partial to horse-hair mattresses, always had the best quality of white hair. As it takes about forty pounds of hair to make a full sized mattress, it will be seen that the cost is somewhat considerable.

One man in the employ of Messrs. William List & Sons, who very kindly gave facilities for this article to be written, can boast of over sixty years' service, while several can claim over forty. The men train their sons, as a long experience is necessary in nearly all the processes.

Messrs. List get the longest tails from China and Russia. These are disinfected before they are handled, as a precaution, and after being dipped in a bath of soft soap and soda, are wet hackled (see Fig. 7) to get out all the short fur. The sorted hairs are dry carded, being piled up on a board which is studded with long pins and drawn from the two ends between an old razor and the thumb to lengths down to five inches (see Fig. 8).

White hair which is thirty inches long and upward is used for violin bows. This is exported largely to Germany by Messrs. List. Black hair, which as we have said before is slightly stronger, is used for the bows for double basses. Shorter hair, according to its length, is tied in bundles and sold to brush makers or to plume makers, for whom it is dyed various colors for ornamenting helmets and the bridles of cavalry horses.

A more extensive use of the long hair is for weaving it into seatings in which a linen warp is used, while the hair cloth which tailors employ for stiffening garments where elasticity is required is made with a warp of cotton. The widths vary from sixteen to thirty-four inches, and it may be pointed out that to produce a thirty-four-inch cloth the hair must be thirty-eight inches long. Some of the hair is of exceptional length, and one tail in an extreme case which passed through Messrs. List's hands measured seventy-two inches. The brown hair is used for fishing lines and was much in vogue years ago for cod fishing. One advantage of the old method was that only healthy fish were caught, while now, it stands to reason, the trawls will bring up all that come in their way, whether they are in good condition or not.

Wigs for judges and barristers are made from what is known as "dead" hair which has no glint upon it, and is specially picked out for the purpose.

The hair from the tails of cows and oxen is also used for one or two purposes. The ends of the tails themselves are brought over attached to the skins and always show a twist. This with the very rarest of exceptions is in one direction. The cow tails are dressed whole and undyed (as are sometimes horse tails from South America), for export to South Africa, where they are used for personal adornment by the natives. The latter insist on the hair being undyed, and they plait it into bracelets and over gourds used for snuff, as well as combine it with the wire which is put over sjamboks and sticks. They also use it for threading beads. North American Indians use dyed hair for the same purpose, and for weaving into their moccasins.

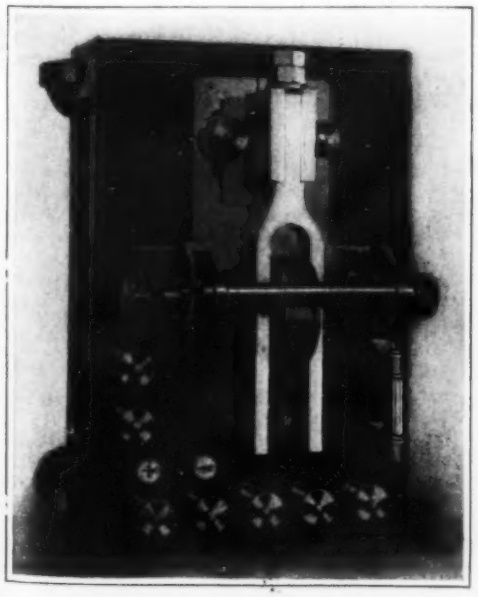
The cow hair is also drawn for weaving into sieve bottoms to form strainers for cooks and gun-powder manufacturers, while horse-hair bags are used for oil and cider presses and for brewers' straining-cloths.

Lastly, goats' hair from China and Tibet, being very soft, is used for babies' brushes.

The Mercadier-Magunna System of Telegraphy

An Improved Method of Multiplex Working

It would seem natural that inventors should long ago have solved the problem of high speed telegraphy, from the fact that this is needed in order to keep pace with the rapidly increasing traffic upon the telegraph lines. A single wire should be made to carry a much greater number of messages than in the earlier days when the demands upon the lines were not as great as they are now. One way to do this is by using some kind of rapid telegraphy method; another is to employ a multiplex system so as to send a number of messages over the wire at the same time. We hear from time to time of very ingenious rapid telegraphy instruments which should greatly increase the speed of sending messages, but the fact that the old instruments are still in use appears to prove that the new high speed methods are not well adapted for practical purposes. This is especially true where photographic processes are used for receiving. As to the other method which consists in sending a large number of messages at once over the same wire, no practical invention appears to be in the field, for in America we find the old Edison duplex still holding the ground. In Europe, printing telegraphs are largely used, and they give a very good speed; for instance, the Baudot printing telegraph has been used as a standard in France for many years past, and it can be operated as a quadruplex, that is, sending two messages each way upon the line. Each message gives 1,550 words per minute, so that we have thus 6,200 words per minute over a single wire.



The Tuning-Fork Transmitter.

We wish to speak of a new method of multiplex telegraphy which is devised by Prof. Mercadier, the well-known Paris scientist, and M. H. Magunna, a leading engineer, who has had great experience in telegraph matters. It is very carefully worked out so that it can be applied to the usual telegraph lines without making any change in the standard instruments or the line, and in this respect it has great advantages. All that is done is to add a greater number of the usual instruments, such as Morse sounders or printing telegraphs. That is, where we now use two sounders on the Edison duplex, six other sounders can be added, making eight instruments in all.

We have already mentioned the principle which Prof. Mercadier proposed a number of years ago for multiplex telegraphy. It consists in the use of vibratory currents on the line in place of the usual direct current. Such currents are produced by tuning fork instruments of special design. To illustrate the principle we may suppose that we have a tuning fork which gives the note *d* and a second fork of the note *a*. We mount these at one end of a table and at the other end we have two similar forks. Striking the *d* fork, we note that the sound waves which it sets up will affect the like fork at the other end and it will sound somewhat faintly, while the *a* fork remains silent. The reverse also holds good, so that each fork will respond only to the proper vibration. But if both forks are struck, both the others will respond and each selects out its proper waves and is acted upon by them and by no others.

Exactly the same principle is used in the Mercadier-Magunna system, except that each fork is vibrated by placing an electro-magnet between the prongs in the usual way so as to make and break the contact for a battery current. Such an electro-magnetic tuning fork will keep on vibrating as long as the battery current is put on. However, the varying magnetic flux, which is set up in the electro-magnet by the vibration of the steel fork, also gives rise to alternating currents, and these can be sent out upon a telegraph line. Such currents have a pitch which is exactly the same as the vibration pitch of the fork, for instance, 500 vibrations or periods per second. At the other station is an identical fork whose electro-magnet receives the current and this causes the fork to vibrate. As above shown, two or more forks can be mounted in a selective system on the same wire. The current from all the forks can be sent out on the line without interfering and each is received in the proper instrument at the far end. To send two messages at once, for instance, it only remains to use a Morse telegraph key with each sending fork so as to make dot and dash signals, not as usual with direct current, but with the vibratory current. As this current has a high pitch, from 500 to 900 periods per second, no difference is found in sending the signals. Each operator sends his message independently and all the waves pass over the

The Selective Receiver.

line without interfering. Message No. 1 is heard only in receiver No. 1, and so on, so that in practice we can send three messages over the same wire in one direction. However, it is to be noticed that this wire can be used to send messages in the other direction as well, seeing that any waves which are sent over the line do not interfere with each other. Just as in ordinary telegraph practice, Station No. 1 has receiving instruments as well, and these take the incoming messages at the same time that the operators are sending messages over the line. We are already familiar with the idea of sending one message each way over the same wire, as this is commonly done on the Edison duplex system. With vibratory currents and selectors, it is practically possible to send three messages each way on a single wire.

Since ordinary messages are sent by using direct current from a battery or dynamo, it is possible to use this direct current on the line wire at the same time as the vibratory or alternating current. Such a method is already well known and it is used for instance in telephoning and telegraphing on the same wire, inasmuch as the telephone produces vibratory currents. The Van Rysselberghe method of connection is used here, so that each kind of current is selected out at the far end and goes into the proper instruments. The inventors take advantage of this fact, and nothing prevents the use of battery current instruments along with those which are operating by vibratory currents. That is, we can use two sounders working as usual by duplex and then add six sounders as above mentioned, working by vibratory currents, making in all eight sounders or four at each station.

In practice, the sounders or other receivers are not actually worked by the vibratory current. In order not to modify them they are operated as usual on a local battery and the vibratory selectors are designed as relays. Instead of a tuning fork, a metal disk is used which is so mounted that it can vibrate for only a certain given pitch and no other. The disk is held up by three supporting screws and under it is an electro-magnet which causes it to vibrate when the proper current arrives, and it then gives a loud sound. On the top of the disk is an electric contact made with a pivoted lever, which rests lightly on the disk. When the disk vibrates, the lever is too heavy to follow it, so that the contact is broken or at least altered, and this weakens the battery current going to its particular local relay which is in turn connected to the sounder. Each mono-telephone relay, as it is called, thus works one sounder or a printing telegraph.

The present method was fully tried on the Government line from Paris to Lyons and it worked very well, sending in all five messages each way over the wire, or 17,000 words an hour.

Vegetable Aviation

Aeronautic Engineering in Nature

THE distribution of seeds by the wind is facilitated, in many species, by appendages analogous to aeroplanes or the wings of birds or insects. Dr. Amans in *La Nature* shows how these structures are perfectly adapted to their function, and accord with the known laws of aviation and aerodynamics. They may be divided into parachutes, monoplanes and helicopters.

Parachutes or Plumed Seeds.—In many compositæ and

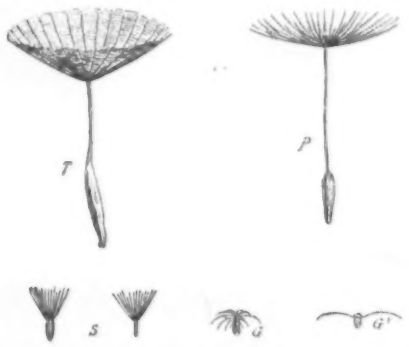


Fig. 1.—Plumed Seeds, *T*, *Tragopodon*; *P*, Dandelion; *S*, *G*, Sow Thistle, *G'*, Soaring Bird.

some other plants, the seed is carried by a plume of hairs like an aeronaut clinging to a parachute. In a common species of dandelion (Fig. 1, *P*) the seed, weighing 1/70 to 1/50 grain, hangs, point downward, by a stalk 4/5 inch long, from a parachute 1 inch broad, composed of about 40 barbed hairs less than 1/500 inch thick. The hairs are inserted at various inclinations, so that the angle between the highest and the lowest is about 60 degrees. The lowest hairs are the shortest and the ends of all the hairs lie in a surface which is convex below.

The seed of the sow thistle or *Sonchus* (Fig. 1, *S*) is attached directly to a simple conical plume of many hairs about 1/2 inch long and 1/1200 inch thick. This type is very common in Compositæ and is found also in other families (cat-tail, willow-herb, etc.). In another type (Fig. 1, *G*) the hairs are concave below, and a vertical section of the plume resembles a front view of a soaring bird (Fig. 1, *G'*).

The seed of *Tragopodon* is attached by a long stalk to a single whorl of hairs, which are connected by a gossamer tissue, forming a cup, convex below.

Bignonia.—The seeds of the bignonia are packed by hundreds in a pod 6 inches long. Each seed (Fig. 2, *A*)

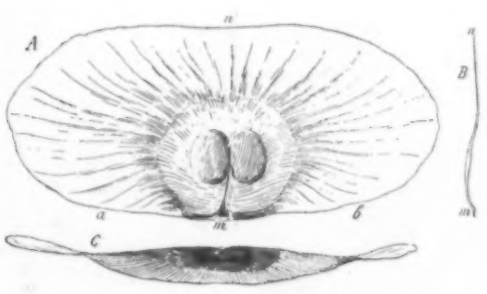


Fig. 2.—Bignonia Seed.

is surrounded by a transparent membrane about 2.6 inches long and 1 inch wide, having the form of an oval which is unequally divided by its major axis. The center of gravity of the seed is on the minor axis, at 1/3 its length from the more strongly curved edge, which is in front, in the gliding flight of this vegetable aeroplane. The section through the minor axis (Fig. 2, *B*) has an undulating form but the other parts of the membrane are flat, so that the seed and membrane may be compared to a monoplane in which the load is concentrated in the frame. The right and left wings, however, are not always equal, and sometimes their tips, like those of a soaring birds' wings, are bent slightly upward. (Fig. 2, *C*). The weight of the seed and membrane is 33 milligrammes or about 1/2 grain and the weight of the membrane is 1/11 of the whole. The total surface is 14 square centimeters. If the dimensions were multiplied by 200, and the weight by the cube of 200, the result would be a monoplane of 13 meters spread and 56 square meters surface, weighing 264 kilograms. Wings of this type would quadruple the carrying power of a monoplane, and more than double that of a Voisin or Farman biplane. A bignonia seed having the spread of wing of a kite would weigh 264 grammes, and have a surface of 0.56 square meters, while the bird weighs 600 grammes and has a maximum horizontal surface of 0.28 square meters. In lightness, therefore, the bignonia seed surpasses birds, flying men and even plumed seeds.

Maple.—Fig. 3 and 4 illustrate the form of the winged maple seed, or "key." The wing portion strongly resembles the wing of a bee or a cicada (Fig. 4, *B*, *C*). The edge *OAD* (Fig. 3) is the thickest part.

The wing of the fresh seed is flat and is shaped almost

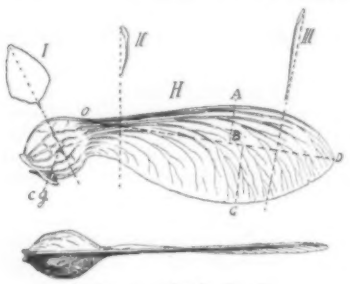


Fig. 3.—Maple Seed.

exactly like a cicada's wing, as the following comparison of proportions shows:

	$\frac{AD}{OD}$	$\frac{OB}{OD}$	$\frac{AC}{OD}$
Maple seed	1/7	0.6	0.4
Cicada's wing	1/7	0.57	0.35

The ratio of the maximum thickness to the length *O D* ranges from 1/40 to 1/20, as in the wings of many insects and birds. The average weight of the whole key is 240 milligrammes (3.7 grains) and the weight of the wing is about 1/11 of the total, as in the bignonia seed. The mean area of the wing is 3 square centimeters. If the dimensions were multiplied by 10 and the weight by 1000 the area would be 300 square centimeters, and the weight 240 grammes. This is nearly the proportions between the weight of a gull and the area of one wing. The center of gravity is situated at 4/7 the length from the apex at 1/2 the widths from the front edge.

Ash.—The dimensions of the winged seed of the ash (Fig. 5) are as follows:

Length	*ol*	35 to 37 mm.	(about 1.5 inches).
Width	*mnp*	9 to 10 mm	(" 0.4 ").

$\frac{on}{ol} = \frac{2}{3}$, $\frac{oc}{ol} = 0.38$ (*c* is the center of gravity).

The seed occupies nearly half the whole length and is, of course, the thickest part, but its thickness is only 1/50 the total length *ol*. The winged seed is twisted, as the illustration shows. The twist is chiefly in the lower, or seed portion, and its total amount ranges from 68 to 78 degrees. The edges are equally thickened and the two faces are alike. The surface includes only two straight lines, *ol* and *ef*, which are not mutually perpendicular. The lines of maximum curvature in opposite directions are *ab* and *kd* (Fig. 5).

The Flight of Seeds.—Plumed seeds fall nearly vertically in the still air, but the lightest breeze produces an oblique descent, or even an ascent. A sowthistle seed often rises when the air appears perfectly still, and thus proves

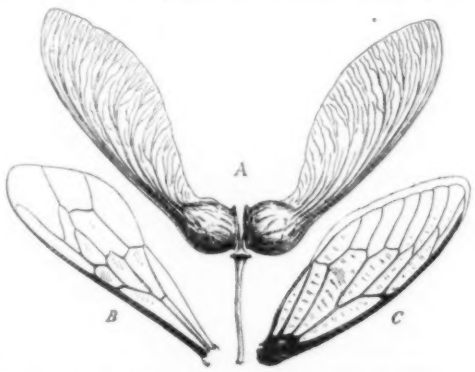


Fig. 4.—*A*, A Pair of Maple Seeds; *B*, Bee's Wing; *C*, Cicada's Wing.

the existence of an otherwise imperceptible upward current. Plumed seeds are excellent current indicators. They oppose much more resistance to the air, per unit of surface, than ordinary parachutes, and are also more stable, because their convexity is directed downward.

If v is the constant velocity of fall in still air, p the total air resistance at this velocity, equal to the weight of the seed, S the area of surface, K the coefficient of air resistance, and $\varphi(\alpha)$ a trigonometrical function of the inclination of the surface, the usual formula is $p = K S v^2 \varphi(\alpha)$. For a dandelion seed $p = 1.4$ milligrammes, $v = 0.4$ meter, and $S = 0.24$ square centimeter. If the hairs are supposed horizontal, $\varphi(\alpha)$ will be 1, and the resultant value of K will be 0.37, and will be smalle than the real value.

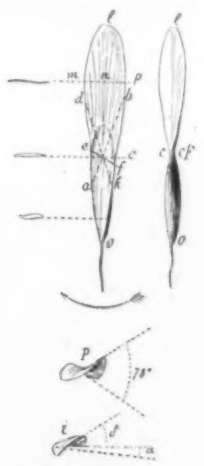


Fig. 5.—Ash Seed.

In the following table it is compared with values of K for objects of various forms:

	K
Cone	0.015
Hollow Hemisphere	0.084
Round wire of 10 millimeters diameter	0.055
" " " 2 " "	0.057
" " " 0.5 " "	0.061
Dandelion plume of hairs of 0.05 " "	0.37

The coefficients for the cone and the hemisphere were determined by Eiffel, and the coefficients for wires by

Chulkowsky. Hence it appears that the coefficient of resistance for a cone is increased twenty-five fold by substituting numerous fine filaments for a continuous surface, and that the dandelion plume is five times better than the umbrella-shaped parachute, with its concavity directed downward. The latter form is never employed in nature, except in the wings of birds, and in this case stability for soaring is given by the upward inclination of the wings (Fig. 1, *G*).

The resistance of narrow flat strips cannot differ greatly from that of round wires. We know that the coefficient is greater for narrow rectangles than for squares, at least at small inclinations. Good results have been obtained in yachting by dividing a sail into several strips. Why not apply the same principle to parachutes and substitute a number of separate strips for a continuous surface?

In still air, a bignonia seed, if symmetrical with respect to its shorter axis, glides obliquely downward in a vertical plane, in a direction inclined about 30 degrees to the horizon, and with the edge nearest the center of gravity in front. The vertical velocity is 40 or 50 centimeters per second. In high winds the seeds may be carried miles from the tree. If the seed is not symmetrical, as is usually the case, it describes a wide helical curve in descending in still air or rising with an upward air current. In still air the vertical velocity of descent is now only 30 centimeters per second.

The seed always falls on its convex face and immediately turns over if dropped with that face uppermost. If dropped with its front edge in contact with a vertical wall it falls to the ground without once leaving the wall. (M. Barbaudy has made little aeroplanes of rectangular pieces of paper, with the front edge thickened and the ends bent with a conical form with the convexity below, which behave in the same manner.)

The maple seed, in falling, acquires a rapid rotary motion which retards its descent. In cities these seeds are often seen spinning above the housetops.

In still air the velocity of descent of the rotating seed is about 1 meter per second. Some seeds with plane and entirely similar faces cleave the air much more rapidly, without rotating. If the faces are unlike, the seed always falls on the more convex face, and rotates with its thicker edge forward. These principles apply to all objects moving through the air.

A maple seed may be compared to a gull with only one wing expanded, which in falling, would rotate toward the side of the folded wing.

If an ash seed is thrown from a window it falls rapidly to a distance of about a yard, and then begins to rotate and to fall more slowly. The velocity of descent, however, is greater than that of the maple seed, and ranges from 1.25 to 1.5 meters per second.

If an ash seed is spitted loosely on a long hat pin, passing through its center of gravity, and an upward current of air is directed against its lower face, while the pin is held vertical, the seed will turn like a windmill, rising or falling according to the force of the current, but always rotating in the same direction—that of the hands of a watch.

The axis of rotation appears to traverse the maple seed at $^6/_7$ and the ash seed at $^3/_5$ its length from the apex of the wing. In each case the long axis of the seed is slightly inclined to the horizon and the convex side is below, so that, if the seed were not falling, the longer segment of this axis would generate an inverted cone, having an apical angle of 140 to 150 degrees. Here, then, as in the plumed seeds, the convexity is directed downward. (I have constructed air propellers with blades inclined backward, forming a convex prow.)

The angle which the axis of a propeller blade makes with a plane perpendicular to the axis of rotation has been ignored by theorists. It may be called the facial angle, and the name angles of profile may be reserved for the angles between the same plane and sections of the blade by cylinders whose common axis coincides with the axis of rotation.

In both maple seeds and ash seeds the facial angle is 15 or 20 degrees. The angle of profile is often constant in the maple seed, but in the ash seed it varies with the radius. The angle of profile plays an important part in theories of the screw propeller. Constructors have invariably adapted an angle of profile which diminishes as the radius increases (negative torsion), but nature adopts positive torsion in the ash seed, the elytra of the stag beetle, and elsewhere. I have suggested the employment of positive torsion in the wings, as well as the propellers, of aeroplanes.

If a rectangular sheet of stiff paper, loaded at its center with 10 times its weight of wax, is allowed to fall from a horizontal position, it will remain horizontal and will fall vertically. If the wax is placed at any other point, the descent will not be vertical. Three cases may be distinguished:

1. If the wax is placed on the short axis, the sheet will descend obliquely, like an aeroplane or a symmetrical bignonia seed, with the long side nearest the wax in advance, the angle between the path and the horizon diminishing as the load is brought nearer to the front.

2. If the wax is placed on the long axis, the result is the same, except that the short side nearest the wax becomes the front. In either case, it would be possible to photograph the trajectory and to plot the position of the center of gravity (the ball of wax) as a function of the angle between the trajectory and the plane of the paper. The curve thus obtained would also give the corresponding positions of the center of pressure which, in stable motion, must lie in the same vertical line with the center of gravity. The ash seed represents a modification of the second case. If the paper is cut to the form of a flattened ash seed, the ball of wax is placed on the long axis at a point o such that $\frac{oc}{ol} = 0.38$ (Fig. 5) and a permanent twist is given to the paper by seizing the ends o and l with the fingers, the sheet will rotate like an ash seed in falling.

3. By placing the ball of wax at points away from both axis we can imitate the wheeling flight of an unsymmetrical bignonia seed and the rapid rotation of a maple seed.

With the principal feathers of birds' wings I have obtained a more complex movement. The feather rotates about its center of gravity, like a maple seed or ash seed, though less rapidly, while the center of gravity describes an irregular helix, like a butterfly. This planetary motion is a combination of the motions of the bignonia seed and the maple seed.

With a sheet of stiff paper having an undulating surface it is possible to obtain a rapid rotation about a horizontal axis perpendicular to the plane of the trajectory, resembling the flight of a tumbler pigeon or the feat of "looping the loop."

Such experiments can be varied indefinitely and will inculcate sound notions of the relations of the sustaining surface to the weight and the air pressure. Toy aeroplanes may be constructed on the models of bignonia, maple and ash seeds, and parachutes of the dandelion and *Tragopodon* types.

Exhaustible and Inexhaustible Supplies

What is Meant by An Unlimited Source of An Article of Consumption?

THE subject of the exhaustion of our natural resources and of the steps to be taken to ward off the danger of a famine in various commodities, has, in the recent past, been discussed widely and in much detail. One might almost think that there was nothing more to be said on the subject, barring the compilation of statistical data. This, however, is not the case, for an anonymous writer in the German periodical *Prometheus* makes some very interesting reflections on the subject from a general standpoint, reflections in which it is worth our while to follow him. The writer asks the question, "What constitutes an inexhaustible supply?" In one sense a given material may be regarded as available in inexhaustible quantities if estimates show that there is enough of it to last the human race for say ten thousand years. For in such a case it is quite aimless to discuss what steps might be taken at the time of the ultimate exhaustion of the supply, since the changes in general conditions which are bound to occur in such an extremely long period, simply cannot be properly gaged. Thus, for example, salt is at present being consumed at the rate of about fifteen pounds per head per annum, and at this rate the supply will presumably be but slightly attacked within say ten thousand years. In such case we may speak of an inexhaustible supply.

This example of salt is instructive in another respect. It shows that abundance of a given material is an advantage only when we are considering from a theoretical point of view the possessions of the human race as a whole. Commercially such abundance is almost tantamount to worthlessness, in accordance with the well-known principle that the price of given goods diminishes indefinitely as the supply increases; hence, if the supply is practically infinite, the price will be nearly zero, and in point of fact the price which we pay for salt covers practically nothing more than the cost of transportation.

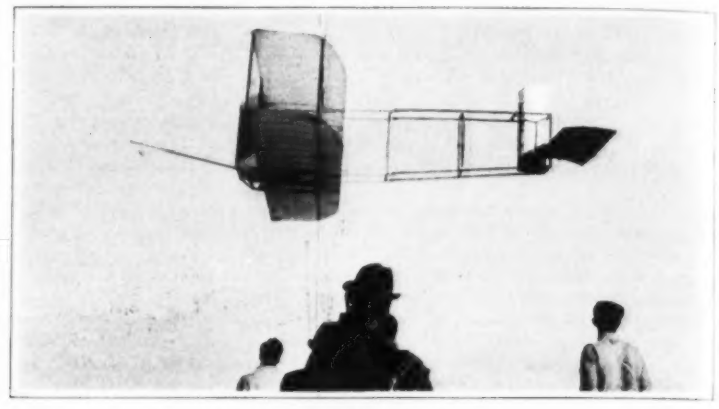
Truly inexhaustible supplies are only those which are being continuously regenerated, running through a cycle of production and consumption. Thus, for instance, all life is inexhaustible, inasmuch as the organisms whose material substances is used up in life and disintegrated at death are continually being replaced by new individuals born into life. In the same way our supply of water is inexhaustible, since no matter how it is used it is always returned to nature, where it becomes purified and is ultimately returned to us in a form in which it can be used over again. Similarly, the air is inexhaustible, not only because it is present in a quantity vastly more than sufficient for our needs, but also because its constituents, oxygen and nitrogen, are continually being regenerated from the various chemical combinations into which they enter in vital and other processes, so that the great reserve stock of our atmosphere remains practically unchanged in composition.

In the case of water and air, also, the same observation can be made as we noted above in regard to salt; great abundance is practically tantamount to commercial worthlessness. We generally think of air as common property which we can always obtain, sufficient for our needs, without having to purchase it. More than this, air has the very obliging property of coming to us unbidden, in proportion as we use it up. Water also is a costless commodity to those who have their abode near fresh rivers or lakes. Under ordinary conditions of city life, however, the cost of pumping the water must, of course, be borne by the consumer, and everyone is familiar with the fact that in certain countries water is bought much as other commodities are. But even air has its price in these days of modern conveniences and inconveniences, for one of the results of the growth of industry is the pollution of the atmosphere, and in selecting the site for our homes, one of the factors which we all take into account is the question of pure air. The privilege of a healthful location is of course paid for, and in this way it might be said that air has been actually purchased. But the matter goes further than this. In the great English capital, which is so plagued with the notorious sulphur fogs, an enterprising concern has undertaken to furnish private houses and public buildings with fresh air from the sea coast, which is fed through a pipe line to the consumer. It is said that the effect of such equipment is very marked, and that the change on stepping from a building thus ventilated to the street is quite striking.

Meat-Curing Electrically.

THAT electricity acts in a sterilizing manner upon organically impure water is well known, and it is therefore interesting to note that at Cleveland, U. S. A., a system of curing meat by electricity has been established by the Electric Meat-Curing Company, in a pioneer equipment for the purpose of demonstrating to packers the practicability of the process on a commercial scale. Curing for the market was commenced on April 10th, 1909, and the electrically cured meat is securing a ready sale on the American market. In this system a series of vats, 14 feet long, 4 feet wide, and 4 feet high, are used, each vat either holding 4,000 pounds of pork or the same amount of beef, and capable of curing 360,000 pounds of bacon, or 48,000 pounds of hams per annum. The demonstration curing-room is designed for twenty tanks, measuring 80 feet by 40 feet. In the tanks the meat is placed in layers, each layer being separated by a wooden rack, allowing the cool circulating pickle to pass through the tank, cooling the meat and obviating the necessity of rehandling the same when once placed in the pickle. Leading into these vats, and the brine solution contained therein, are carbon electrodes. The electric equipment consists of one transformer for twenty vats or less, a volt-meter and a meter for controlling the supply to the whole system, and a switch and rheostat for each vat, in which are ten electrodes, five at each end. Hourly readings are taken of the volts and amperes taken by each vat. The cost of energy per vat is about 10d. per every twenty-four hours' run at ordinary power rates, and a large saving is effected in the cost of pickle. In the older process it was necessary to boil or sterilize the pickle after each cure, while in the electric process the number of cures which can be made with the same pickle is indeterminate. The method adopted is to give each electric curing vat three hogsheads of pickle at the start. One hogshead of fresh pickle for each vat in use is added to the old pickle after two cures of 4,000 pounds each. Thus electric current forces into each 8,000 pounds of meat the ingredients of one hogshead. The adding of one hogshead of pickle brings the saturation up to requirements. The U. S. inspector stationed at the plant has forwarded to Washington a sample of pickle taken after twelve cures. The fact that water can be taken from a stagnant pool filled with all kinds of poisonous germs, and be made chemically pure by the electric current, warrants the assertion that throwing away pickle is unnecessary with the electric cure. It is not necessary to separate pickle on account of its age, for this system keeps the solution as fresh and pure as when first made.—*English Mechanic and World of Science.*

Note the Warped Wings.



The Glider Poised in the Air.

ORVILLE WRIGHT HOLDING HIS GLIDER STATIONARY IN THE TEETH OF A GALE

The Undeveloped Art of Soaring

Its Theory and Practice

By Dr. A. F. Zahm

For many decades two kinds of passive flight have been recognized in nature and have been understood to be achievable by man. One is volplaning, or gliding downward by the force of gravity; the other is soaring, or gliding by force of the wind without loss of altitude. Human volplaning has been so far perfected as to no longer be a novelty, if indeed it does not excel the master performances in nature. Human soaring is a much neglected art, though capable of astonishing development, an art of perennial and fascinating interest, which may now be cultivated with enhanced facility by reason of the increased efficiency of the glider and the aeroplane.

The permanent art of passive flight dates from Otto Lilienthal's experiments near Berlin, in the early nineties of the last century, though long previous to that time some wonderful feats of gliding and soaring, of both men and models, were reported by reliable witnesses. Lilienthal made numerous glides several hundred feet in length, down hill slopes, sometimes pausing in the air, or rising considerably above the level of his launching place. Sometimes also he wheeled about and returned nearly to his starting point. He was succeeded by various disciples, who improved the control of the glider and to some extent its efficiency. A contemporary of his, rather than a disciple, Prof. Montgomery,[1] after twelve years of study, launched a glider in 1905 from a balloon 4,000 feet in the air, bearing on its back a dauntless aeronaut, Maloney, who by means of wing warping and a double rudder guided it, with many a playful dip and wheel, securely down to a designated spot, where he landed in safety. With a like aerial glider, another Montgomery aeronaut cut corkscrews in the air. These feats far surpass in altitude and endurance all glider records up to the present time. The record for volplaning in a power machine, which really becomes a glider when the motor stops, is held by Lincoln Beachy, who, during the Chicago meet of 1911, glided sheer down to earth in a Curtiss biplane from an elevation of 12,654 feet.

The records for soaring are briefer, and some are not so well attested. In 1859 Capt. Le Bris, piloting a glider patterned after an albatros, soared 300 feet high and descended safely to earth. This on the authority of De la Landelle, who wrote a history of aeronautics published in 1884, and who had the account from Le Bris's neighbors. Mouillard, nearly twenty years ago, soared 138 feet over a prairie after an initial run and jump across a roadside ditch with a glider strapped to his waist.[2] Many recent aeroplanists have been carried well upward by rising wind currents. During the gliding experiments of Chanute and Herring one of the operators was raised by the wind some forty feet high, then landed almost in his tracks without serious shock. Lateral glides along the hillside were also made, one forty-eight seconds in length, which showed the possibility of patrolling to and fro in such places. Mr. Atwood relates that while flying over a mountainous country he once encountered an upsloping current which lifted him over a thousand feet high. As described in a recent issue of the SCIENTIFIC AMERICAN, Orville Wright was supported on such an ascending current above a hill slope for nearly ten minutes, sometimes stationary, again gliding forward or backward, and sometimes rising to considerable elevation above the starting point. These various experiments are good indications of what may be expected when the possibilities long ago revealed by science are put to the test of adequate experiment.

The fundamental postulates of the mechanical theory of passive flight are very simple. They are well expressed by Lord Rayleigh in the following paragraph:[3]

"I premise that if we know anything about mechanics, it is certain that a bird, without working his wings, cannot, either in still air or in a uniform horizontal wind, maintain his level indefinitely. For a short time such maintenance is possible at the expense of an initial velocity, but this must soon be exhausted. Whenever, therefore, a bird pursues his course for some time without working his wings, we must conclude, either (1) that the course is not horizontal, (2) that the wind is not horizontal, or (3) that the wind is not uniform."

Rayleigh's first postulate covers the case of volplaning which is accomplished on a generally downward course. The second and third postulates comprise all cases of soaring ever yet adequately observed in art or nature. In our present state of science no other cases are admissible. Many observers, it is true, testify that a bird can soar in a uniform horizontal wind, or in a dead calm which is its mechanical equivalent for that purpose; but such flight is beyond the power of aerodynamics to explain, if indeed, it be not equivalent to perpetual motion.

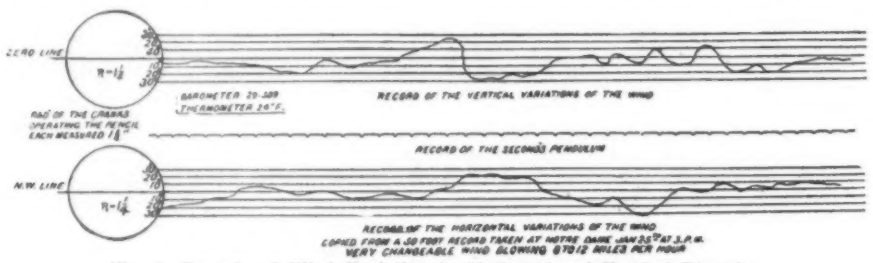

ZERO LINE
BAROMETER 29-309
THERMOMETER 26°F.
RECORD OF THE VERTICAL VARIATIONS OF THE WIND
RECORD OF THE SECOND PENDULUM
N.W. LINE
RECORD OF THE HORIZONTAL VARIATIONS OF THE WIND
COPIED FROM A 30 FOOT RECORD TAKEN AT NOTRE DAME JAN 25TH AT 3 P.M.
VERY CHANGEABLE WIND BLOWING 6 TO 12 MILES PER HOUR

Fig. 2—Records of Wind Variation in Horiontal and Vertical Direction.

Soaring then is possible only in ascending air or in a wind of variable velocity.[4] In other words, it is possible, (1) in an ascending flow of air, (2) in a horizontal striated flow, in which the stream-lines are all parallel but the velocity varies in neighboring striæ, or strata, (3) in a horizontal wind of fluctuating speed, (4) in a horizontal wind of fluctuating direction, either horizontal or vertical. The chief types of maneuver for such conditions may be considered briefly here, as also the prevalence of such conditions. Of course, this classification does not hold rigorously in nature, but may be assumed for the purpose of simplifying the analytical treatment.

Fig. 1 presents the well-known graphic analysis of soaring in an ascending current. If the oblique arrow represents the relative wind, and the other arrows the horizontal and vertical components of its pressure on the flier, this will hover still in space when the vertical component just equals the weight, and the horizontal component just neutralizes the head resistance. Obviously also the flier will advance or recede, rise or fall, according as these components of wind force prevail or be overpowered. If further the surface be tilted, it will have a third or lateral wind force tending to produce motion sidewise, so that the flier may glide to right and left across the wind

Fig. 1.—Diagram of Wind Pressure on Aeroplane.

as well as in the other two rectangular directions. In an ascending wind therefore a passive flier can hover still, or advance in any direction. This species of flight has been understood from time immemorial; for it is practiced by all kinds of birds, even poor sailers, and is easily accomplished by any skilled avaitor in favorable conditions.

Any skilled volplaner who wishes to practice soaring would therefore do well to follow the long standing advice of mathematicians, and choose a sandy slope up which a wind blows at any angle rather in excess of the flattest angle of descent possible in still air. The slope should preferably face the sea or a broad even stretch of land. If, furthermore, the slope be wide, the aviator may soon learn not only to hover, to advance and recede, but also to patrol the entire slope to and fro laterally. As an instance of such procedure, the writer has seen a crow, which usually beats its wings continually in flight, soar to and fro on rigid wings along a stone wall across which a stiff breeze was blowing, and at times also rise and descend, advance and recede, then instantly take to violent beating when caught in the general current away from the wall.

Obviously, continuous soaring is possible on a rising current whose vertical component equals, or exceeds, the slowest possible rate of descent of the glider when coasting down still air. If, for example, a bird in calm air can glide at a speed of twenty miles an hour down a slope of one in ten, it can soar continuously in a current rising with a vertical component of two miles per hour, while an equally efficient flier moving sixty miles an hour would require, to maintain soaring, a current rising at the rate of no less than six miles an hour. From this it follows that the slowest and most amply surfaced gliders like butterflies require the least ascensional trend of air for soaring. Still such fliers are far from being good soarers because of their incapacity to acquire sufficient speed and momentum to cleave swift winds and drive their way for a considerable time in spite of unfavorable conditions.

Ascending winds due mainly to uneven temperature distribution and to inequalities of terrene prevail very generally over the globe. Lilienthal concluded from instrumental observation that the general trend of the wind is three degrees upward. His was of course a local and empirical study. But on principle it may be quali-

[1] It is with deep regret that we note the death in the cause of science, of Prof. Montgomery, which occurred on October 31st., 1911.—ED.

[2] Chanute, "Progress in Flying Machines," p. 130.

[3] *Nature*, April 5th, 1883.

[4] Let it be technically explained that a wind of variable velocity is one that varies in speed, in direction, or in both.

tatively affirmed that the general course of the wind is slightly upward. For the rising air is, on the average, warmer than the descending air; hence its volume displacement is greater; hence its general direction of flow is slightly upward. This effect is intensified where the air from a surface of water or vegetation passes over a barren or desert soil. Ascending vortices are very abundant, particularly over a heated terrain exposed to direct sunshine. Meteorology teaches that every isolated cumulus and thunder-head marks the top of an uprising column of hot air. All heated slopes, especially in the early part of the day, produce updrafts, particularly if they be long and barren. Precipitous islands and coastlands cause strong ascending currents which the sea birds know so well how to use. Over the desert numerous columns of sand, reveal the rising vortices continually. On torrid planes large isolated trees have a powerful uprush of air above them, initiated doubtless by the tree itself from the hot stratum of air beneath. Thus the skillful soaring bird finds abundant elevators as he coasts about the atmosphere, which he may use to gain sufficient altitude to prolong his meandering glide till he encounters the next elevator, whether this be a vortex or merely an upward deflected wind.

Soaring in a truly horizontal wind whose speed varies considerably at neighboring levels, or in different striæ at the same level, is easy to understand in theory. The bird or hier acquires sufficient speed in the swifter stratum to enable it to glide into the lower stratum, there reverse its direction and return in the teeth of the swifter current, to be again caught up and given a new high speed as before. Many instances are reported of such flight in nature but none in human art. The theory has been presented

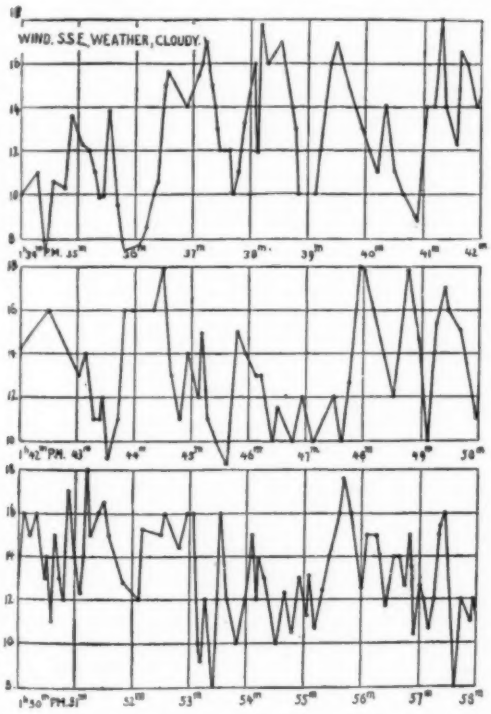


Fig. 3.—Records of Wind Speed Obtained by Langley.

by Lord Rayleigh in his "Mechanical Principles of Flight," by Vogt in London *Engineering*, and by various other writers; but the actual performance still challenges the skill and cunning of the practical aviator. The fact that the wind moves in neighboring strata and striæ is well established, but is it still to be proved quantitatively that the rate of change of speed is quite commonly sufficient to support prolonged passive flight.

Soaring in a horizontal wind of pulsating speed has been qualitatively explained by Dr. Langley, and quantitatively studied by Chanute and others. The general theory conceives that the flier faces the direction of the wind, rises and drifts backward when the wind freshens, sinks and advances during the lull. This explanation is valid providing the horizontal acceleration of the wind be sufficient. Langley, therefore, recorded the pulsations of wind speed by means of very light cup anemometers to obtain a physical basis for his theory.

The records, Fig. 3, show quite remarkable fluctuations in speed, but not sufficient to maintain soaring in any flier of art or known nature up to the present. The total forward resistance of a well formed aerial glider, or bird, may be taken as one-eighth of its weight; hence if poised stationary in its normal altitude of flight, it will be just sustained by a direct head wind having a horizontal accelleration of one-eighth that of gravity, or four feet per second. This is obviously true of all gliders, whether swift or slow, whose total resistance equals one-eighth of their weight. Now, the most favorable parts of the record here shown exhibit nowhere an acceleration so great as four feet per second, and on the average show far less than that, as may be seen by scaling the diagram. Hence the wind here recorded was wholly inadequate to support by its pulsative force either bird or man. As this record is a fair representative of all those published by Dr. Langley, it follows that such pulsations can at best merely aid in soaring when happily and adroitly encountered; but that they cannot fully sustain soaring at any level, much less during ascensional flight to great altitudes, or migrational flight over vast distances. This conclusion is applicable even to those gliders which are reported to require a propulsive force of but one-fifteenth or one-twentieth of their weight. Hence to account for soaring in a horizontal wind of fluctuating speed it seems necessary to postulate a pulsating breeze of far greater acceleration than those recorded by Dr. Langley in his paper on "The Internal Work of the Wind." Fuller and more varied records of pulsations in the wind's velocity may be found in the *Interim Report* for 1909 of the British Advisory Committee for Aeronautics.

In a horizontal wind that pulsates in direction merely from side to side, soaring may be aided by the alternate impulses of the air against the flier, resisted by its inertia. If the wind freshens well from the right quarter and the flier lists to port, it will be driven to port; then if the wind blows promptly from the left quarter, while the flier is tilted to starboard, it will have its acquired component of momentum to port reversed and will drift to the right. In each case the oblique lift on the wings may have a component generally forward tending to overcome the entire head resistance. The magnitude of this forward component of the normal pressure on the tilted flier is easily seen to be, at any instant, equal to the product of such normal force multiplied by the sine of the angle of tilt and by the sine of the angle between the quartering wind and the forward course. If, for example, each of these angles be 30 degrees at any instant, the propulsive component is one-fourth of the whole normal component, which of course would be ample to overcome all resistance. Continuous soaring in such a laterally pulsating current would, however, require phenomenally rapid and wide fluctuations of wind direction, and great alertness on the part of the flier. The case is worth notice as showing that a glider can receive both support and propulsion from a quartering wind, and can even tack successfully like a ship if the horizontal fluctuations in directions be suitable.

In a generally horizontal wind that undulates up and down, soaring may be aided in various ways, if not continuously sustained. If the aerial vibrations be strong and rapid, as in a fluttering wind, they may exert a sculling action on the wing as a whole or on its flexible rear margin. In such case the narrow flexible wing of the bird would be more effective than the broad stiff wing of an ordinary aeroplane, though of course narrow and pliable pinions can be used in aeroplanes and gliders to adapt them to soaring in fluttering winds. Such sculling action may occur in wind undulations of considerable period and amplitude, as where the air follows the contour of the billows in a heaving or tempestuous sea, particularly if the flier glide across the undulations at considerable speed, like the albatross, thus greatly increasing the apparent frequency of the rise and fall of the air.

Mouillard likens soaring in such heaving air to the motion of a marble on a wavy groove in a vertical plane which a skilled man moves up and down in such opportune manner as to cause the marble to ascend rapidly on a long wavy slope. The comparison is a good one except for the fact that gliding on the yielding air is less efficient than sliding or rolling on a rigid track. But if the potential energy can be rapidly acquired on the Mouillard track, perhaps also on the aerial track increased, altitude can be attained under favorable circumstances.[1]

In case the undulations of the air be due to a vortex rolling about a horizontal axis while advancing with the wind, as supposed by some writers, the bird or glider might remain on the ascending side of the vortex and thus obtain continuous support while advancing with the speed of the rolling vortex whether fast or slow. Such a performance might seem marvelous or paradoxical to the witness, since the rolling vortex must be quite invisible, but the feat would be no more remarkable than some reported by aviation experts who claim to have witnessed the passive flights of aquatic birds for thousands of feet just over the surface of still water in a hardly perceptible breeze. The rolling vortex of Chanute and Herring offers fascinating possibilities. The aviator need only saddle his glider deftly on this transparent Pegasus to go kiting all over creation. But the fine art is to locate and lasso such a wild wind-horse.

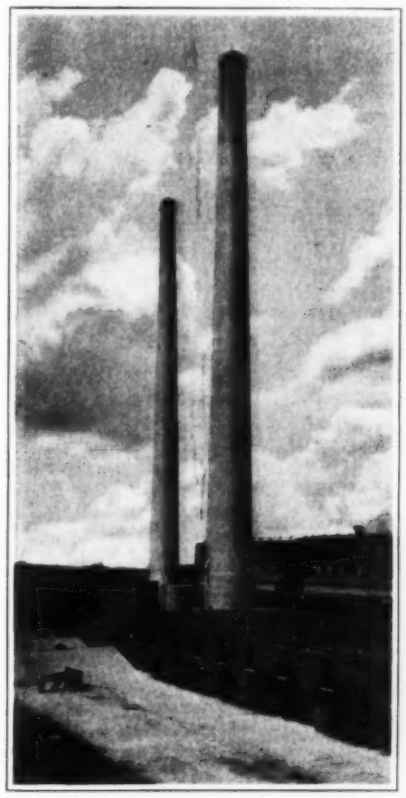
Fig. 2 exhibits typical records of the changes in wind direction, both horizontal and vertical, obtained by the writer by means of a special recording wind vane exposed in a clear open space of 200 acres, and in a wind of eight to twelve miles an hour. The diagram shows that the wind veered quite frequently ten degrees in a short interval of time, and not seldom twenty to thirty degrees. In strong winds the fluctuations of both velocity and direction are generally more marked than in moderate winds, as has been often observed in meteorological records. Hence they furnish a good physical basis for the belief that soaring may be materially aided, if not continuously sustained, by pulsating winds.

[1] The present writer has caused a model glider to ascend on a wavy course in the air by pulling vertically down on it intermittently with a thread. Such gliding seems a fair representative of soaring in a wind oscillating rapidly in a vertical plane.]

Giant Twin Stacks.

Two remarkable chimneys at Rochester are seen in the accompanying illustration, both of which are 366 feet high above the top of the foundations. The smaller one measures 9 feet in internal diameter at the top and the larger one 13 feet; both are constructed of radial brick. They have a 4-inch lining throughout, laid in acid-proof cement, with 2-inch air space. Each chimney has a connection for acid fumes in addition to the flue for boiler gases. The foundations run down to rock and are about 22 feet in depth. The Kodak Plant, where these chimneys are located, is equipped with two and three-fourths miles of water mains for fire protection purposes, with thirty-seven hydrants, 4,800 feet of hose and seventeen hose houses. The buildings are all equipped throughout with automatic sprinklers of which there are about 10,600 heads and there is a reservoir with a capacity of 600,000 gallons, used for the storage of clean waste water.

The first chimney when built was the tallest in the United States and is 28 feet in diameter at the base, outside dimensions. The concrete octagonal foundation is 40 feet across, 23 feet deep and contains 915 cubic yards of concrete. The larger chimney also 366 feet high is 31 feet diameter at base, outside dimensions. The combined capacity of the two



These Stacks Are 366 Feet High.

chimneys will equal 18 to 20,000 boiler horse-power. The power house contains 16 boilers with a rated capacity of 4,800 horse-power, actual capacity about 6,000 horse-power. Above the boilers are located coal bunkers having a capacity of 3,200 tons, from which the coal drops through chutes to mechanical stokers. The waste gases from the furnaces pass through fuel economizers.

About 120 tons of coal are burned per day, the ashes being removed by a mechanical conveyer. There are being added to the above equipment 4 boilers of 2,000 rated horse-power which will bring the total rated capacity up to 6,800, and the actual capacity to about 8,500 horse-power. There are five engine-driven generators in service with a total capacity of 1,800 kilowatts, or 3,000 horse-power, furnishing electricity for light and power to the various buildings throughout the plant.

A total of 888 motors, ranging in size from one-twelfth to seventy-five horse-power are required to operate the machinery in these buildings. There is at present being installed in addition to the above equipment one 1,600 horse-power engine connected directly to a 1,000 kilowatt generator, giving a total of 4,600 horse-power. In all, more than 9,000 incandescent lamps and 65 arc lamps are used for lighting. Refrigeration for cleaning and drying air, for cold storage rooms and ice making is provided by eleven ammonia ice making and refrigerating machines with a total capacity of 2,320 tons per day.

The Mechanical Principles of Brennan's Mono-Rail Car*

A Lucid Exposition

By Henry T. Eddy, University of Minnesota

[This paper is an endeavor to develop by brief elementary methods the mathematics and physics of the gyroscope, and their application to Brennan's Mono-rail Car. The writer is of the opinion that anyone who is familiar with elementary mechanics will be able to understand this paper and use the equations in practical design. The relations developed are so simple and the proof so plain that it is hoped that they will assist in perfecting the design of various sorts of balancing devices by revealing clearly the secret of the mechanical principles involved in them. Outline: (1) Account of trials of Brennan car. (2) Analogy of centrifugal and gyroscopic action.. (3) Equilibrium of the car under unbalanced loads. (4) Equilibrium of the car running on a curve. (5) Limits of stability of the car. (6) Nutation during the establishment of equilibrium.]†

EARLY in 1907, Louis Brennan, the inventor of the Brennan torpedo, exhibited before the Royal Society of England a working model of a mono-rail car which was able to preserve its equilibrium perfectly while in motion or at rest, while traveling around sharp curves, while running on a swinging cable, or subjected to sudden shifting of load from side to side. The apparatus by which automatic balance is preserved in this remarkable manner consists of a pair of heavy fly-wheels mounted on the car which rotate at high speed in opposite directions about axes transverse to the car. The gyroscopic effect of these rotating wheels prevents the car from toppling over, somewhat as a top is prevented from falling while spinning.

On November 11th, 1909, a further demonstration was given with a full-sized car in the War Office grounds of Great Britain at Chatham, England. Accounts state that the car which was there operated with entire success was 40 feet long, 10 feet wide and 13 feet high, and weighed 22 tons. The car ran on a single rail around a circular track 220 yards in circumference at a speed of 25 miles an hour, carrying a load of 40 passengers on its platform where they had entire freedom of movement. The balance was automatically preserved by the action of two gyroscopes 3½ feet in diameter, weighing three-fourths of a ton each, and revolving at the rate of 3,000 revolutions per minute. The gyroscopes run in a vacuum to reduce friction. A gasoline engine was used to propel the car and keep up the speed of the gyroscopes.

It is reported that a German mono-rail car is soon to be exhibited embodying the same principle, of which the motive power will be electrical. Indeed, synchronous motors would apparently furnish an ideal means of keeping the two gyroscopes in step with each other, and the trolley would be a natural means of propulsion for such a car.

Models to illustrate the working of the Brennan car constructed in this country from the designs of Profs. Crew and Tatnall, Northwestern University, are accessible to the public, as shown in Fig. 1. It is said by the makers, to embody the following essential points, which are here quoted from their published statement, with a few emendations and amplifications:

A. The use of two gyroscopes or fly-wheels, mounted side by side in frames, as shown in Fig. 1, and rotating about a horizontal axis in opposite directions with equal speed. The precessional couple about an axis lengthwise of the car, due to the turning of the car about a vertical axis in rounding a curve, is equal and opposite for the two gyroscopes, hence the upsetting torque arising from this source vanishes.

B. The employment of a pair of shelves or plates as friction surfaces, attached to the sides of the car, one on each side. When the car begins to tip over to one side, one of these shelves is raised and begins to press against the rotating end of the gyroscope axle, which projects over it. This pressure causes the gyroscope to turn, or precess, about a vertical axis. The frame of the second gyroscope is geared to that of the first in such a way that it is forced to turn equally in the opposite direction, as shown at the top of Fig. 1. The axle, on account of friction on the shelf along which it tries to roll has a force exerted on it whose moment tends to increase the precession. The moment of this frictional force about a vertical axis has the effect, not to increase the precession already taking place, but instead, to cause precession about the horizontal axis. The opposite moments acting on oppositely rotating gyroscopes conspire to cause precession in the same direction about the longitudinal axis of the car. This rights the car and tips it slightly to the other side, to be brought back again by the second shelf. The center of gravity of the whole car is thus kept oscillating very slightly on either side of the line of upward thrust of the rail.

C. The use of a second pair of shelves next to the first pair, each engaging an idle roller whose friction is negligible, attached to the gyroscope frame, and serving to return the frame, after displacement, to its normal position, transverse to the car.

D. The use of a single central frame in which both the gyroscope frames turn, or precess, which is itself solidly mounted on an axis lengthwise of the car, and on the same level with the gyroscope axes, so that this frame and the gyroscopes it carries can together tip to the right or left with reference to the car, or the car can be tipped with reference to them, to an amount determined by the clearance between the shelves and the gyroscope axes over them.

This description of the car and its action will become more clear after following the developments in the following:

Gyroscopic action has up to the present time not been regarded as one of the available devices for securing mechanical effects in machine design, but rather as one to be avoided, and where unavoidable, one to be guarded against in the same manner as is done in most cases of centrifugal action. For example, the centrifugal force tending to burst a fly-wheel must be carefully guarded against in design and operation, but on the other hand centrifugal action is boldly made use of as the essential element of design of engine and turbine governors of all sorts. In the same way the gyroscopic action of armatures on shipboard must be carefully provided against. But as appears from this invention, we must, hereafter, be prepared to make use of the peculiar properties of gyroscopic action to produce mechanical effects that are otherwise unattainable.

To this end, it is the purpose of the present paper to set forth the principles of gyroscopic action in general and, in particular, to describe their application to the mono-rail car, in such an elementary and geometrical form as to make the action intelligible and calculable without recourse to complicated mathematics. This may be done most readily by help of the close analogy, or say identity, which exists between the mathematics of centrifugal action and that of gyroscopic action.

This we now proceed to develop. Suppose a body of mass m revolve in the horizontal plane of Fig. 2 about C to which it is attached by a string of length r. If the linear velocity of m along the circle of radius be v, then it is well known that the tension of the string

$$t = \frac{mv^2}{r} = mu^2r = mvu \qquad (1)$$

in which the deviating (or centrifugal) force t continually draws m away from the straight path it would

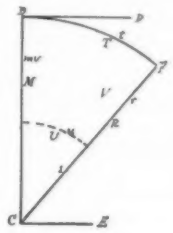


Fig. 2.

otherwise follow along a tangent to the circle, and u is the angular velocity of revolution, i. e., the linear velocity of a point on r at the distance of unity from C. Equation (1) may be written in the form

$$1 : mv :: u : t \qquad (2)$$

from which it appears that if the distance $r = CB = CF$ be taken on some arbitrary scale to represent graphically the numerical amount of the momentum mv, and it be laid off at right angles to the direction of the momentum along BF, viz., at successive instants along r in its successive positions, then on the same scale the length of the arc BF at right angles to the successive positions of r measures the impulse of the deviating force, which is numerically the same as the tension t, the tension at any instant being at right angles to the arc, just as mv at any instant is at right angles to the position of r at that instant.

The elementary considerations by which equation (1) is established will not be here developed, as they may be found in any treatise on the mechanics of motion. Equations (1) and (2) express a necessary relationship of the mechanical and physical quantities concerned. For example, the tension t can be increased only by some suitable change in one of the other quantities, such as using either a greater mass m, or imparting to it a higher velocity v, or making r, the radius of the circle of motion, smaller.

Now in order to develop the corresponding equations for gyroscopic action, let us assume that a gyroscope or fly-wheel whose moment of inertia about its axis of rotation is M is rotating with its axis initially horizontal at CB. It is to be noticed that the actual linear motion of its particles in space is at right angles to CB, as was the linear motion of m previously treated. Let the axis have a point of support at C only, and let the center of gravity of the total weight W sup-

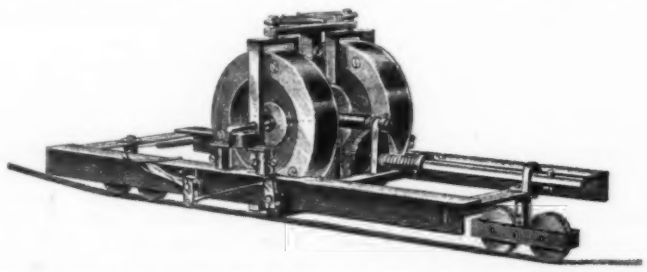


Fig. 1.—Model to Illustrate the Working of the Brennan Monorail Car.

ported at C be situated at B, a distance of $CB = R$ from C, so that it requires a couple of torque $T = WR$, combined with a vertical force at $C = W$ (the weight acting at B) in order to keep W from falling. Let the gyroscopic wheel revolve about CB with an angular velocity V, then its constant angular momentum about CB is MV.

On some arbitrary scale let $R = CB = CF$ be taken to represent graphically the numerical amount of the angular momentum MV. On the same scale the arc $BF = T$ may be taken to represent the deviating angular impulse of the torque T, which is numerically the same as the torque T. This angular impulse continuously generated by W at right angles to the angular momentum MV is to be compounded with it in pre-

---

* *Journal of the Franklin Institute.*

† Since the time when Foucault, in 1852, applied the gyroscope to demonstrate ocularly the rotation of the earth on its axis and the precessional motion of the latter, various efforts have been made to utilise gyroscopic action for practical purposes. The first, and until within recent years, the only attempt in this direction of which there is any authentic record, is that of Prof. Piazzi Smyth, who, in 1856, devised a telescope stand provided with a gyroscopic apparatus calculated to maintain its level while supported on the constantly changing plane of the deck of a vessel at sea. The apparatus was tested by Prof. Smyth on board a naval vessel in the course of a sea voyage and, according to authoritative reports of the experiment, was found to serve its purpose. It appears, however, that the mechanism was too complicated for regular use. About 1897 an Austrian engineer, M. Obry, applied the principle of the gyroscope, namely, the tendency of the fast-revolving wheel to maintain its given direction in space, for the purpose of automatically steering a torpedo. His invention was subsequently perfected and successfully applied by the Whitehead Torpedo Co. In 1904, Herr Otto Schlick brought out before the British Institute of Naval Architects a gyroscopic mechanism which was subsequently developed into an apparatus to prevent the rolling of ships at sea. This appliance was successfully demonstrated in 1906 in experiments on a German torpedo-boat, and in 1908 was practically applied on an English steamship by the Neptune Works at Newcastle. About the same time, according to report by United States Consul-General Wright, from Munich, April, 1905, another German inventor, Dr. Anschütz-Kämpfe, produced an apparatus in which the gyroscopic principle of maintenance of direction in space is applied as a compass. Experiments with this instrument on board a German warship appear to have proven it capable of replacing the magnetic needle under conditions wherein the latter is unreliable. The latest practical application of the gyroscope as represented by the Mono-rail Car of Mr. Louis Brennan was the subject of a lecture by Prof. W. S. Franklin of Lehigh University before the Institute at a meeting held in February last, and the following paper affords a lucid demonstration of the principle involved.—ED.

cisely the same manner that the linear impulse generated by the deviating tension t is compounded with the linear momentum mv; instant by instant, during its generation, in order to produce a uniform deviation in a circle.

The torque T due to the weight W at B acts always at right angles to the axis of the angular momentum MV just as the tension t at B acts always at right angles to the linear momentum mv, hence MV and T must be compounded according to the same laws as mv and t.

Therefore

$$1 : MV :: V : T \qquad (3)$$

or

$$T = MVU = \frac{MV^2}{R} = MU^2R \qquad (4)$$

in which U is the angular velocity of R about C in the horizontal plane and the gyroscope is said to precess or turn at the rate U. The apparently paradoxical action of the gyroscope consists in this, that while rotating about one axis a torque acting on it apparently tending to turn it about a second axis at right angles to the first, actually does turn it about a third axis at right angles to the other two, and this is its only effect.

Equation (4) may also be written:

$$W = \frac{T}{R} = \frac{MVU}{R} = \frac{MV^2}{R^2} = MU^2 \qquad (5)$$

These equations (3), (4), and (5) express physical relations that must necessarily exist in gyroscopic action during dynamic stability of motion. They show, for example, that a decrease in the rotary velocity V through friction or otherwise would require a more rapid precession in U in order to support the given weight W, a fact readily observed; or again, V remaining unchanged, any increase in W will produce a corresponding increase in U, as appears at once experimentally.

In order to comprehend clearly how the direction of precession is related to the rotation and torque, suppose the rotation of the gyroscopes appear clockwise to an observer looking from B toward C, then to an observer looking from D to B gravity tends to make the axis BC rotate about C, so that the impulse of T is clockwise also, about a horizontal axis EC, which is parallel to the tangent at B, to an observer looking from E to C.

This angular impulse of T, generated instant by instant, is continuously compounded with the constant angular momentum MV. Since it acts always at right angles to MV, its effect is not to increase or decrease MV but solely to change its direction, so that the axis of rotation R is steadily moved forward to successive positions intermediate between BC and EC and thus at the end of a unit of time it occupies some position CF. It will evidently move to a position between BC and EC whenever both are clockwise, which will therefore also make the precession U clockwise when the observer looks down on C.

Careful attention should be given to the relative directions of rotation just indicated for the three quantities TUV, which are arranged in alphabetical order, are mutually at right angles, and are so situated with respect to each other that they follow each other cyclically clockwise to an observer looking toward C from any point in the solid angle between them, and they each indicate clockwise rotation to an observer looking along either of them toward C. Considered in this way it is not difficult to analyze gyroscopic effects into clockwise actions, since every rotation is clockwise for one aspect or the other. It further appears that a force applied at right angles to W in an attempt forcibly to increase or decrease the precession U would fail to do so, but would instead produce a precession in a vertical plane, thereby causing W to rise or fall according to the above rule. It would greatly assist the student of the mono-rail car to use a pair of graphical models made of corks into which three pins of different kinds are stuck at right angles, one along the axis of the cork to represent V or MV, and two others at right angles for T and U respectively, placed in the order mentioned above.

In all this discussion of centrifugal action and gyroscopic action it will be noticed that we have carefully confined our attention to the relation between the external applied forces and the motions ensuing, and have not considered the equal and opposite internal forces that are developed in the form of reactions in equilibrium with the applied forces. This has been done for the sake of simplicity and to avoid all possible confusion as to cyclic order, etc. Its correctness as a method can no more be questioned than can its application to the case of motion of a falling body where the external force of gravitation acts and motion ensues, and no regard need be had to the fact that by its inertia the body develops an internal reaction equal and opposed to the force of gravitation.

A vertical transverse section of the gyroscopic equilibrating parts of Brennan's mono-rail car may be represented in diagram as in Fig. 3, and in horizontal section or ground plan in Fig. 4, in which the same letters refer, so far as possible to corresponding parts in both figures at once.

The arrangement consists of a pair of gyroscopes revolving on horizontal axes B_1C_1, B_2C_2 at the same speed $V_1 = V_2$ in opposite directions, so that a spectator looking along either axis from B_1 to C_1, or B_2 to C_2 will see the wheels rotating clockwise.

This speed is to be maintained by applying so much power as may be necessary to overcome friction, preferably by synchronous motors upon the axes BC. The axes BB are carried in bearings in the vertical frames which are shown in Fig. 3 in the form of circular rings. These rings swing about vertical axes $D_1D'_1$,

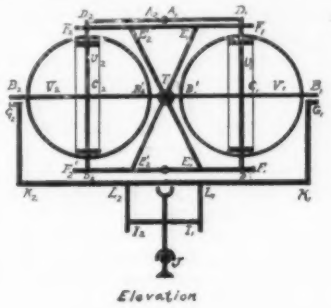


Fig. 3.

$D_2D'_2$ which in turn are carried in bearings in a vertical framework EF rigidly fixed to an axle TT. The axle TT which lies lengthwise of the car, which is represented in cross section by GKL, is solidly supported by bearings in the car, vertically above the rail J and the car wheel, which last revolves about the horizontal axis I_1I_2.

In Fig. 4 the gyroscopes are represented in a position which they would assume after having suffered a small deviation from their mean normal position (in which BB and TT are mutually at right angles) such as would occur after a small precessional rotation had taken place.

The gyroscopes are kept in step with each other in their motion about their vertical axes DD as well as in their motion about their horizontal axes BB, so that their rate and amount of precession about DD is always equal and opposite. This first result is effected by means of two toothed sectors A_1 and A_2, which engage each other and which are rigidly attached to D_1 and D_2 respectively by arms AD which may be regarded as right angled prolongations of D_1 and D_2. Thus the arms AD turn with the rings about the vertical axes DD and we thus have $U_1 = -U_2$, as well as $V_1 = -V_2$, so that the rates of precession are equal and opposite as well as the rotary velocities.

The fact that both gyroscopes are carried by the rigid frame EF requires, however, that any turning of the gyroscopes about the axis T_1T_2 which is perpendicular to both BB and DD, shall be the same for both gyroscopes and in the same direction, not in opposite directions. Let this condition be expressed by the equation $U'_1 = U'_2$, in which U'_1 and U'_2 are precessions about T_1T_2.

In Fig. 3 the car is represented as in perfect balance in a horizontal position, but this is not the case in Fig. 4. Suppose an unbalanced load be placed upon the right side of the car between L_1 and K_1. That would tip the car and bring the plate at G_2 into contact with the rotating prolongation of the axis B_2C_2 at B_2.

This plate consists of two parts, a rough part G_2 intended to act as a friction brake on B_2 and a smooth part H_2 on which the axis B_2 can rotate without friction. As soon as this plate exerts an upward pressure upon the axis at B_2 the unbalanced load is transmitted

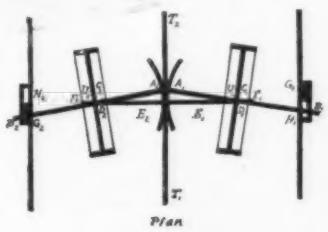


Fig. 4.

to the gyroscopes in the form of a torque about T_1T_2 and the action is the same as though a pair of equal weights were hung upon the right hand half of each gyroscopic axis whose combined torque is the same as that of the unbalanced load. As already explained the effect produced upon the gyroscopes is not to cause any revolution about the axes about which T acts, but instead to produce precession about the vertical axes DD.

The right hand gyroscope then has its three clockwise actions TUV situated as already described in our treatment of the gyroscope, Fig. 2, and its precession is clockwise as we look upon it from above as represented in Fig. 4; while the left-hand gyroscope having a clockwise rotation V_2 observed from B_2 and a clockwise T looking from T_1 to A_2 must have a clockwise precession U_2 viewed from below, thus producing the precession represented in the left gyroscope, Fig. 4.

The sectors A_1A_2 are therefore unnecessary so far as this action is concerned. But it is otherwise with respect to the action of the friction plate G_2. For, as the axis at B_2 rolls upon G_2 a horizontal force is exerted on B_2 which exerts a torque T_2, say, about the vertical axis D'_2D_2, clockwise when viewed from below, in its effort to increase the rate of precession U_2. This it is unable to change. Instead of causing an increase in the precession U, the torque T_2 will cause a precession U'_2 about an axis at right angles both to MV_2 and U'_2, i. e., about T_1T_2.

Let T' designate the torque of any couple produced by friction tending to turn either gyroscope or both about a vertical axis in a clockwise direction, then by equation (4),

$$T' = MVU' \qquad (6)$$

gives the value of U', the precessional angular velocity produced about the horizontal axis T_1T_2, to right the car and bring its center of gravity to a position vertically over the rail. That this statement is correct is evident upon considering the necessary relative position of $T'_2U'_2V_2$ for the left gyroscope, since they may be regarded as acting independently of TUV previously treated. The graphical model will show that the precession U'_2 is such as to right the car by giving it a precession opposite to the torque T of the unbalanced load, which precession will diminish and cease as the car is righted.

We have here considered the left gyroscope as if it alone were effective in righting the car. In fact both gyroscopes conspire to produce the same effect, for one-half of the torque T' is transmitted by the toothed sectors AA to the right gyroscope in which T' is, therefore, clockwise seen from above and U'_1 is clockwise looking from T_2 to A_1. This action therefore brings a mechanical stress on the toothed sectors to transmit part of T' from one gyroscope to the other, and in equation (6) M is the sum of the moments of inertia of both gyroscopes.

It is evident since the car shown in Fig. 3 is in unstable equilibrium that left to itself it must immediately incline to the one side or the other. We have just shown how the gyroscopes act in case of an unbalanced load to return the car to the position of unstable equilibrium for car and load together.

Suppose now that the car tips still further in the direction in which the gyroscopes have been operating to right it, so that from unstable equilibrium it begins to tip over and down to the left, while the axes of the gyroscopes have stopped in the position shown in Fig. 4, as they would, since there is no unbalanced load to maintain precession. The first effect of this initial inclination to the left would be to bring the smooth plate H_1 into contact with the right axis at B_1. Whatever might be the force which H_1 exerted to press B_1 upward, its only effect would be to produce a precession about the vertical axes DD in the opposite direction from that which was produced when G_2 pressed B_2 upward. This precession about DD will serve to restore the axes BB of both gyroscopes to their normal positions transverse to T_1T_2, but it will not be accompanied by any precession about T_1T_2 until B_1 reaches G_1.

The effect of the plates G and H combined with the very small clearance between them and the axes is ordinarily to limit the deviations of the axes BB from their normal transverse position to very small amounts, for any tipping is almost instantaneously corrected and relatively large unbalanced loads may be applied suddenly without large disturbance of the gyroscopes. We shall return to this matter later.

The discussion thus far has considered what occurs while the car stands still or moves upon a straight track or cable. A single gyroscope would have been sufficient to produce all the results reached so far. The two have, however, been shown to act in unison so far, and the two become necessary only by reason of the forces brought into play in rounding a curve in the track.

So far as the centrifugal force which is developed in running the car around a curve is concerned, it acts precisely like an unbalanced load in applying an angular impulse about T_1T_2 to tip the car off the track. We have already explained in detail how the gyroscopes operate to balance the car on the rail in such circumstances. It should be remembered that in rounding a curve the car is in balance not when its center of gravity is vertically over the rail, but instead, when it lies in the line of the resultant of the centrifugal force and gravity, just as it must also stand inclined in case of sidewise wind-pressure.

The one thing, however, which we have not yet con-

sidered is the torque developed in each gyroscope about the longitudinal axis T_1T_2 by reason of the common precession of both gyroscopes in the same sense with the car itself about a vertical axis in rounding a curve in the track. Were it not for the toothed sectors A_1A_2, the axes B_1B_2 would both maintain their original direction in space while the car turned the curve, but, unable to do this by reason of A_1A_2, they are both forced to precess with the car. Suppose the car moves in the direction T_1T_2 around a curve that turns to the right as A_1 does, then the precession is clockwise viewed from above, and the torque developed in the right gyroscope is formed by placing our cork model of TUV with V to the right, U vertical and T horizontal, so that T acts about T_1T_2 and clockwise looking from T_1 to T_2, while the torque in the left gyroscope is about T_1T_2, but clockwise looking from T_2 to T_1, as will be readily perceived by comparing the cork model before mentioned with U upward in the two while V in one case is opposite to that in the other.

The two gyroscopes, therefore, develop equal and opposite torques about T_1T_2 which are transmitted to the rigid frame EF through the bearings DD and they hold each other in equilibrium by means of internal stresses induced in the frame. While running around a curve to the right a tension is caused in F_1F_2 and an equal compression in $F'_1F'_2$.

The gyroscopes are both needed in this case in order that each may equilibrate and neutralize the torque of the other, which would otherwise infallibly overturn the car on attempting to run it round a curve. Furthermore, it is evident that in order to secure the existence of this dynamic equilibrium it is necessary that the two axial velocities V be at all times equal and opposite.

It is not, however, necessary that V remain, at all times, constantly of the same value. The high speed of 3,000 revolutions per minute proposed by the inventor is for the purpose of insuring that the product MV on which the stability of the car depends shall be large without making the size and weight of the gyroscopes large. He estimates that for ample stability their weight may then be only 4 per cent of the weight of the car, or less.

Under those conditions the gyroscopes would store so large an amount of rotary energy (which is measured by $\frac{1}{2}MV^2$) that the fluctuations of velocity V, due to the expenditure by friction on G_1G_2 and otherwise, would be practically imperceptible in case the power applied by the synchronous motors to maintain V is sufficient in the long run to make good all losses by friction. In any case the power needed by the gyroscopes would be inconsiderable compared with that required for the propulsion of the car.

The foregoing discussion has all depended upon equation (4) and its applicability to the gyroscopic interactions actually occurring in the proposed arrangement. Equation (4) assumes that the axes BB are in their normal transverse positions at right angles to T_1T_2. But owing to the precessions about DD we are compelled to consider what modifications are necessary in order to take into account the effect of such deviations in the positions of BB as may take place. Let d designate the amount of this angular deviation from the normal position at any instant. Then the angular velocity V may be regarded as made up of two components, viz., $V \sin d$ about an axis parallel to T_1T_2 and $V \cos d$ at right angles to T_1T_2, of which the latter component alone is effective in equation (4) which may be written:

$$T = MU'V \cos d \qquad (4)$$

From this it is seen that with a given torque T the precession U increases with the deviation d, though the deviation is in fact usually confined to such small values that the precession is but slightly varied from this cause.

The practical effect so far as balancing is concerned is the same as if the gyroscopes were in normal position with axes at right angles to TT, and rotating with velocities $V \cos d$, and besides that there was an additional pair of gyroscopes exactly like these mounted on axes parallel to T_1T_2 and rotating with velocities $V \sin d$. The effect of these latter, were they in action, will be readily seen to be nil so far as unbalanced loads on the car are concerned, as well as their effect on the centrifugal action in rounding a curve; but not so in regard to the precessional effect in rounding a curve, which precession, as previously remarked, consists in a turning of the whole car including the gyroscopes about a vertical axis.

In case the gyroscopes stand at a deviation d while rounding a curve the stresses before described as produced in FF are diminished in the ratio of V to $V \cos d$, the latter being the component of the angular velocity of the gyroscopes in the plane of the frame. Besides this stress, a twisting stress is induced in the frame by the angular component $V \sin d$, the component rotation parallel to T_1T_2 which exerts a torque about an axis perpendicular both to the axis of precession which is vertical and the axis of rotation TT, i. e., about CC. This torque, therefore, consists of equal forces parallel to T_1T_2 applied to the frame at the four points D_1, D'_1, D_2, D'_2 such that those at D_1 and D'_2 act in one direction and those at D_2 and D'_1 in the opposite direction, thus causing a bending stress in the frame EF so that the torque exerted by one gyroscope is neutralized by the other, and the effect upon the car is nil.

It thus appears that no disturbance of the balance occurs by reason of the deviation caused by the precession occurring during the righting of the car. The sole effects are some slight variations in the rate of the precession and in the stresses to which the frame is subjected, matters which have no influence upon the action of the gyroscopes in righting the car.

It is furthermore evident that the gradual or instantaneous elevation of one end of the car above the other, such as might occur in running on a slack cable would, since it is a precessional rotation about an axis parallel to CC, have no effect, at least while the axes BB are in their normal position perpendicular to TT. The almost impossible case of such precession taking place during the continuance of a deviation d of perceptible magnitude could also be readily discussed, but is practically negligible since the deviation d actually flutters back and forth each side of zero in almost infinitesimal instantaneous excursions that check every attempted lapse from an upright position at its very beginning, and simultaneously with the attempt, the only lag in action being the time required for the movement necessary to tip the car far enough to reduce the clearance between the axis at B and the plate GH to zero. That clearance may be made as small as desired.

The question that naturally arises respecting this car, in the mind both of the engineer and the layman, is as to the limits of its stability. How much of an upsetting torque is it able successfully to withstand? It is evident that the larger the moment of inertia and rotary velocity of the gyroscopes the greater the stability, as appears also from equation (5). Brennan has stated that the weight of the gyroscopes need not exceed some 4 or 5 per cent of that of the car. In his experimental car their weight is nearly 7 per cent of the unloaded car, but perhaps may not exceed 4 or 5 per cent of its total weight when loaded.

The point of danger in the apparatus is reached when the precession U has been so long operating as to carry the deviating axle B_2 (Fig. 4) to the end of the friction plate G_2. The car must be righted before the deviation reaches this point or the car will upset. A deviation of more than 30 degrees would apparently by unpracticable, and in practice 10 degrees or 15 degrees is probably nearer the limit.

In order that the car be righted with such promptness as to avoid this danger, U' in equation (6) must be large, which in turn requires T' to be large. Now T' is the torque about a vertical axis due to the friction of the axle B_2 as it rolls and slides upon G_2. This torque T' depends upon the product of the pressure of B_2 upon G_2 and the coefficient of friction between these. It has already been shown that the precession U is unaffected by T'. It is U' alone that is affected by T'. Now it would seem that the only thing necessary to make U' of any desired amount would be some means of increasing T' *ad libitum* before the deviation reaches its limit. To ensure ultimate safety either the coefficient of friction should in some manner be made to increase enormously before the limiting deviation is reached, or the pressure between B_2 and G_2 should be enormously increased in some automatic manner before reaching that limit. It would appear quite practicable to so arrange magnetic coils about B_2 as to have an electric current pass through more and more of them as B_2 approaches its limit of deviation and by that method automatically increase the magnetic pressure between B_2 and G_2 to any desired extent as the limit is approached, thus making T' and consequently U' both increase enormously at the limit. It would seem as if some such device must be adopted if occasional overturning from high winds and other accidental causes are to be avoided. The inertia of the gyroscopes in Brennan's experimental car is not known as yet, but computations based on assumed data make it probable that a very high wind causing a pressure of 30 pounds per square foot against the sides of a car of ordinary construction might cause a total precessional deviation of 30 degrees in a fraction of a second, from which the suddenness with which the car must be tilted to oppose the wind may be inferred and the necessity for some such automatic safety clutch is evident.

There is an action of the gyroscope still remaining which it is important to consider in connection with mono-rail car, which action is included under the head of "nutation," so called. The actions treated thus far in this paper have not taken into consideration the inertia effects which are brought into play about the vertical and longitudinal axes of the car by reason of the sudden or gradual application of unbalanced loads. Consider the effect of weight W suddenly applied at B in Fig. 2. The discussion heretofore given treated the precessional motion as already established and its steady continuance was insured by the moment of W acting about C. In suddenly applying a weight W at B we have to consider the phenomena occurring during the establishment of the precession due to W. This precession, consisting in a constant, angular velocity about a vertical axis through C, must necessarily arise by the application of an angular acceleration (constant or variable) about the same axis which is resisted by a corresponding couple (constant or variable) due to the inertia of the gyroscope.

During the establishment of the precession due to W there is therefore a resisting couple about the vertical axis due to inertia, which acts in addition to everything previously taken into account. Such a couple produces precession about CE (Fig. 2) in such a way as to allow W to begin to move downward. This is clearly what should occur, since the precession does not become large enough to support W until the precession reaches the value required by equation (5).

The motion just described is the beginning of the nutation. The precession about the vertical will gradually increase until it is sufficent to support W were it at rest, but by that time W has acquired a velocity and momentum such as to carry it still farther downward before it can be stopped. In thus being stopped in its course, W by its inertia exerts a couple which continues to increase the precession beyond the amount necessary to simply support W, so that by the time W has ceased to move downward the precession is so large as to give W an upward velocity during the time necessary to reduce the precession. It may readily be shown that W will be carried upward to the level from which it started, while the precession will also be diminished to the value it had to begin with. This oscillation of W up and down in unison with the increase and decrease of precession occurs harmonically, and constitutes the nutation.

In case the weight W is applied uniformly and gradually during the nutation, so that the whole of it is applied in course of the downward motion, it is evident that it will have half as much effect in causing nutations as if applied suddenly.

The relations just stated would enable us to investigate the amplitude and period of the oscillation were it important to do this. But as will now be shown such oscillations should not arise in the mono-rail car and hence we omit the investigation.

In the mono-rail car the friction plates are designed for the very purpose of producing a couple about the vertical axis opposed to the inertia couple which causes nutation. If properly designed the friction couple neutralizes and greatly exceeds the inertia couple due to any load likely to come upon the car. It will then happen that the car will not give way under an imposed load at all but will begin at once to bring the center of gravity of load and car over the rail without any preliminary nutation, which would be a motion in the opposite direction. It might be possible, however, for a weight falling from a sufficient height to set up a small oscillation.

A Mountain as an Obstacle to Wireless Telegraphy

ACCORDING to *L'Industrie Electrique*, as quoted in *Cosmos*, it has been observed repeatedly on board the "Themistocles" that when this vessel was stationed west of Cape Otway (at the southern tip of Australia) it was impossible to communicate with vessels situated in the port of Melbourne. This has been attributed to the fact that the mountain which forms the Cape contains large quantities of metallic minerals, which absorb electric waves.

TABLE OF CONTENTS

PAGE

Alloys.—By Albert A. Somerville..... 322

A Proposed Catalytic Furnace.—By E. C. Smith..... 323

Roman Ruins in North Africa.—3 illustrations..... 324

Stamping Out Yellow Fever in Brazil.—By Robert Grimshaw.—2 illustrations..... 325

Finger Prints.—By Henry Faulds.—4 illustrations..... 326

The Genesis of the Rare Earths.—By Dr. R. Bohm..... 327

The Zoological Side of Commerce.—By Hubert H. Poole and Wilfred Mark Webb.—8 illustrations..... 328

The Mercadier-Magunna System of Telegraphy.—2 illustrations..... 329

Vegetable Aviation.—5 illustrations..... 330

Exhaustible and Inexhaustible Supplies..... 331

Meat-curing Electrically..... 331

The Undeveloped Art of Soaring.—By Dr. A. F. Zahm.—5 illustrations..... 332

Giant Twin Stacks.—1 illustration..... 333

The Mechanical Principles of Brennan's Mono-rail Car.—By Henry T. Eddy.—4 illustrations..... 334